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ELEMENTARY BIOLOGY

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ELEMENTARY BIOLOGY

PLANT, ANIMAL, HUMAN

BY

JAMES EDWARD PEABODY, A.M.

HEAD OF THE DEPARTMENT OF BIOLOGY, MORRIS HIGH SCHOOL
BRONX, NEW YORK CITY, AUTHOR OF "STUDIES IN PHYSIOLOGY" AND "LABORATORY EXERCISES IN ANATOMY
AND PHYSIOLOGY"

AND

ARTHUR ELLSWORTH HUNT, PH.B.

HEAD OF THE DEPARTMENT OF BIOLOGY, MANUAL TRAINING
HIGH SCHOOL, BROOKLYN, NEW YORK CITY

> "The wild life of to-day is not wholly ours to dispose of as we please. It has been given to us *in trust*. We must account for it to those who come after us and audit our records." — HORNADAY.

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TO

THE MEMORY OF

MARTHA FREEMAN GODDARD

WHOSE DEVOTED INSTRUCTION IN BIOLOGY IS A LASTING

INFLUENCE FOR GOOD IN THE LIVES OF HUNDREDS

OF BOYS AND GIRLS AND WHOSE RARE SKILL

IN LEADERSHIP IS AN INSPIRATION TO

EVERY TEACHER WHO KNEW HER

THIS BOOK IS DEDICATED

BY THE AUTHORS

PREFACE

ALL the activities of a plant, of an animal, or of man may be grouped in three classes. One class embraces the functions relating to the life of the individual organism. These functions have to do with the processes of eating, digesting, assimilating, taking in of oxygen, producing of energy, and excreting of waste matters. These may be called *the nutritive functions*, if the term is used in its broadest sense. To the second group of activities belong the functions that have to do with the perpetuation of the animal or plant species, and these are known as *the reproductive functions*. Living organisms, whether plant, animal, or human, may, in the third place, be considered in their relations to one another and especially to *the general welfare of mankind*. Thus we may discuss the beneficial or injurious effects, so far as man is concerned, of different kinds of insects or of various types of bacteria; we may learn of the activities of individual men or of groups of individuals which promote or retard the advance of human society; or we might, if we were to carry the study still farther, even seek to learn the ways by which the higher thoughts of mankind, as expressed in poetry, music, and religion, affect the development of the human race.

In the preparation of this text, the authors have sought to keep continually in mind these three classes of activities, and to unify the study of plant, animal, and human biology by choosing those topics for laboratory work or text description that have to do in a broad sense with one or the other of the three great groups of functions of living things to which we have just referred. In doing this, they are conscious that many subjects have been slighted or altogether omitted which might well be treated in a year's work in either botany, or zoölogy, or human physiology.

Again, in the treatment of a given subject, for example, stems, fishes, or circulation, special emphasis might be laid on structure, on function, or on the relation of the given topic to human life. Books both interesting and scientifically worth while could be prepared along any one of these lines, or, if time permitted, all three phases might be equally emphasized. But when we remember that less than two hundred school periods will probably be devoted by the average student to the study of biology, the necessity for adhering pretty consistently to some one plan is obvious.

In the judgment of the authors the kind of biology most worth while for the average boy or girl of fourteen years of age is *not one based primarily on structure.* Young students are naturally more interested in activities or functions than they are in mere form or structure. Hence, if we wish to work with, rather than " against the grain," we must put function in the foreground of our discussion. Every boy and girl knows, too, that both plants and animals as well as human beings must have food and drink, and that they grow and reproduce their kind. It is relatively much easier, therefore, to unify a course like this along physiological lines than on the basis of morphology, or of homologies of structure, many of which are far too complicated to be made clear to young students.

If properly outlined and presented, there is probably no subject in the school curriculum that can be made of more service to a growing youth than can biology. Biological problems confront him at every turn, and if he is a normal being he will have asked himself question after question which an elementary knowledge of biology ought to help him to answer. Some of these questions may be the following: Whence comes the food and oxygen supply used by man? Why are food and oxygen needed in our bodies? Why are some substances beneficial to the body and others injurious? What is the cause of disease, and how is disease transmitted? And if we were to tabulate the biological questions that occur spontaneously to the average pupil in the first year in the high school, we should doubtless find that a great proportion of these questions had to do with the relation of the living world to human life. Is it not clear, therefore, if we are to outline a course in biology that will best fit the interests of the "live material," *i.e.* the boy or girl who is to take the course, that the central idea or factor must be man; that all the various functions considered must have some relation to human life; and that the course, to be of practical importance, must suggest to the youth better ways of carrying on his own life and of helping to improve the surroundings in which he lives?

In order, however, to treat intelligently such a function, for example, as respiration or digestion, it is of course necessary to know something of the machinery by which each of these processes is carried on, and so there must be at least a minimum consideration of the structure of plants, animals, and the human body. In every case, however, the authors have called attention only to those details which seem to be absolutely essential for an interpretation of the function under consideration. Whenever names in common use are sufficiently accurate for descriptions, these are chosen in preference to scientific terms. Frequently the latter are necessarily used, and so, whenever their meaning is made clearer by referring to their derivation from Latin or Greek, these derivations are indicated in parentheses.

The sections in coarse type contain the material that seems to the authors most essential for any clear understanding of the subject as a whole, while in fine type we have put additional laboratory work and text description which we believe to have an important bearing on the various topics discussed. If both coarse and fine print on animal, or plant, or human biology are used, sufficient material for a half-year course in either elementary botany, zoölogy, or human physiology will be provided.

In the judgment of the authors, plant biology should always be considered first and human biology last in the course for the following reasons: (1) Plants lend themselves far more readily to close observation and especially to experiments than do animals, and so fundamental processes which apply to all living things can be demonstrated scientifically from plant material. (2) Plants are the final source of all the food supply of animals and man, and if the composition and manufacture of the nutrients are taught early in the course, a solid foundation is laid for all subsequent study of nutrition in animals and man. (3) The purpose of the animal study is largely that of showing the adaptations of animal structure to functions and the relations of the animals studied to human welfare. (4) And finally, if human biology comes last in the course, it may be presented in such a way as to review, sum up, and give real significance to many of the facts learned earlier in the course. In fact, as the work proceeds, comparisons will constantly be made between plants, animals, and man to show that the essential differences in the three kinds of organisms consist not in the differences in the functions which they carry on, but in the organs by which the functions are performed.

So far as the order of individual topics under plant, animal, and human biology is concerned, the instructor should plan the sequence that best fits the season. In fact, the last use that a good teacher will make of any laboratory manual or text-book is that of following it slavishly. It is the hope of the authors, however, that the laboratory guides and the text descriptions which follow may be sufficiently suggestive to help some teachers to work out improved methods in biological instruction. In Appendix II will be found a suggested order of topics which the authors have found satisfactory.

Living organisms are to a large extent to be regarded as chemical engines so constructed as to liberate different kinds of energy. No one, of course, knows in any ultimate sense how even the simplest functions are performed by the simplest animals or plants. But it is utterly useless to attempt to teach biological functions without first presenting some of the elementary principles involved in physical and chemical phenomena. For this reason the first chapter in Plant Biology is devoted to the study of the Composition of Lifeless and Living Things. In Chapter III is a brief discussion of the structure of a common plant, and since cells are fundamentally alike in structure and functions in all living organisms, emphasis is laid early in the course on the essential characteristics of these cellular elements in plants. Another topic which necessarily recurs throughout plant, animal, and human biology is the principle of osmosis and its applications. The authors have inserted experiments which in their experience have helped to fix in mind this important principle and which demonstrate the necessity of digestion in plants and animals.

After this brief consideration of the fundamentals of plant composition, structure, and processes, Chapters V, VI, and VII are devoted to the study of the adaptations of plants for performing nutritive and reproductive functions. In

Chapter VIII are grouped experiments and descriptions the aim of which is to show various ways in which plants are propagated. This treatment presents only the briefest statement of underlying principles, since any extended discussion of this topic belongs to a course in agriculture.

In Chapters IX (Plants in their Relation to Human Welfare) and X (Plant Classification) the method of presentation is strikingly different from that adopted in the rest of the book, particularly so in the treatment of the spore-bearing plants. The authors believe that every pupil should be taught something of these simpler forms (especially bacteria), and that he should get as many of these facts as possible by observation. But to expect much laboratory work from young students on difficult microscopic forms like many of these cryptogams, is, we are confident, quite out of the question. We have, therefore, frankly abandoned the inductive method of study and have suggested that the laboratory work be largely in the nature of demonstrations. It is, of course, understood that if these forms are studied, the drawings and descriptions will be prepared from material in the hands of the student.

In our judgment there are few if any biological topics which are more important in their practical bearings than is that of bacteria. As commonly studied the disease-producing effects of these organisms are emphasized so much that boys and girls do not appreciate that all the work of the higher plants depends ultimately upon the activity of these low forms of fungi. In order to bring out this aspect of the work of bacteria and for other obvious reasons the structure, physiology, and economic benefit of these organisms are considered in the chapter on the relation of plants to human welfare, while their pathogenic effects are reserved for discussion in human biology.

The method of presentation in "Animal Biology" is somewhat different from that employed in "Plant Biology," for the reason that several widely different types of animals are studied. Limitations of time compel a rigid and somewhat narrow selection of groups for intensive study, and only those functions of each animal are considered which have some relation to human biology, or which have a broad, economic bearing. Thus insects are discussed largely because of their injurious or beneficial effects upon mankind; birds and fishes, because of their economic importance, and because of the great need for their conservation; and one-celled animals because of the light they throw on cellular processes. Certain other somewhat less important topics are considered incidentally; for example, protective resemblance and metamorphosis among insects, and the striking adaptations of structure to function in the bills, feet, and feathers of birds.

The animals suggested for additional study, if time permits, are representative mammals, reptiles, amphibia, arthropods, molluscs, worms, and cœlenterates. In many classes there are students who can work faster than the others, or who are interested in pursuing further their biological studies. Such students may be directed in carrying on some of these studies either in class or outside of school hours. In any case, students are likely to acquire considerable information by reading these textbook descriptions and studying the illustrations.

All the work of the year should lead up to and culminate in human biology. Here, too, however, many important topics must be treated only superficially, or altogether omitted, on account of lack of time. The authors believe that in this, the most important part of the course, practical hygiene should be taught as effectively as possible, and that the necessity for good food, pure air, varied exercise, and sufficient sleep should be continually emphasized. If boys and girls can be led to conform their daily habits to the principles of healthy living, the course in biology will have its highest justification.

In the treatment of Stimulants and Narcotics, the authors have tried to state in simple language the conclusions of experts regarding the effect of tobacco and alcohol, and to present the strongest scientific arguments against the use of these substances which are so injurious to growing youths.

No study of human biology should be allowed to leave in the mind of the student the idea that he is merely a chemical engine adapted only for the generation of a certain amount of physical energy. The primary object of all secondary education should be the development of character and efficiency, and the true teacher ought to find opportunity again and again to touch the individual life of the young student. Especially should this be true in the study of biology. Growing boys and girls ought to come to feel, as they have never felt, that they have in their keeping a most complex and wonderful piece of living machinery which can be easily put out of order or even wrecked. But, on the other hand, they should see that if the bodily machine is well cared for, it is capable of splendid work which may help to increase the sum total of human efficiency and happiness.

In the preparation of this book the authors have received a great many suggestions from the teachers in their own departments and those of other schools. Our thanks are due to Miss M. Helen Smith of the Manual Training High School, Brooklyn, N.Y., for several laboratory outlines which formed the basis of corresponding studies in the following pages. The authors have been especially fortunate in securing the constructive criticism of Dr. C. Stuart Gager, Director of the Brooklyn Botanic Garden of the Brooklyn Institute of

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Cost prices for the items on the list of laboratory apparatus and equipment were kindly furnished us by Bausch & Lomb, Kny-Scheerer, and O. T. Louis; from these prices the estimates on pp. 173 to 177, Appendix I, were prepared.

J. E. P.
A. E. H.

December 31, 1912.

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PLANT BIOLOGY

View in the Hemlock Forest, New York Botanical Garden. — (Courtesy of New York Botanical Garden.)

PLANT BIOLOGY

CHAPTER I

GENERAL INTRODUCTION

1. Lifeless Things and Living Things. — As we look about us, we find that the world in which we live is wholly composed of two classes of things, which we commonly speak of as *living things* and *lifeless things*. Soil, air, and water, for example, we know to be lifeless. Water is probably the simplest of these three so far as its composition is concerned. Soil, on the other hand, is very complex in composition, being formed of nearly all the substances known to the scientist. Enveloping the earth is a mixture of gases called the atmosphere which extends outward in every direction for a distance of about fifty miles. Everybody knows, too, that over the surface of the earth, in the water, and even in the air are countless numbers of living things which we designate as either plants or animals.

One might think that it would be an easy matter to set down the characteristics by which living things are distinguished from those that are lifeless. And such is the case when we compare a rock in a field with a horse that is feeding beside it. Unlike the animal, the lifeless rock is unable to move itself, it neither eats nor breathes, and it gives no evidence of feeling or of will power.

But suppose we select for comparison a railroad locomotive and a horse. Both move; both need a plentiful supply of air;

both develop heat and power to do work; and both give off certain waste matters. The horse, we may say, requires food, but so does the engine; for coal and water are as necessary for the development of heat and power in the engine, as food and water are for a similar purpose in the horse.

When we try to state characteristics that will distinguish all plants from all lifeless objects, we find the task still more difficult; for most plants do not move about from place to place, it is difficult to realize that they give off heat, and they do not give evidence that they have conscious feelings as do the common animals. In spite, however, of these similarities, we are usually able to distinguish living from lifeless objects at least by the three following characteristics.

2. Growth of Living Things. — In the first place *living things use some of the food they eat for growth.* No one ever heard of an engine or other lifeless object beginning as a small machine, and then slowly growing larger until it comes to have many times its former weight.[1] Yet this is what happens to all plants and all animals. The average child, for instance, at birth weighs seven to eight pounds; while a man's weight is over twenty times as great. And if we try to compare the weight of an oak tree with that of an acorn from which it started, the amount of increase we find to be enormous.

3. Repair of Living Things. — In the second place, parts of a locomotive or of any other lifeless machine by continual use become worn or broken, and the engine must be sent to the machine-shop for repairs. Our bodies, too, are being constantly worn away; for every time we make a motion of any sort, some of our living muscle is used up; every time we think or exert our will power, some of the living brain substance is probably changed into dead waste material. But in contrast to lifeless machines, *our bodies are self-repairing*. The food we eat not only goes to increase the size of the body; it also furnishes material to make good the wear and tear of everyday life. This power of self-repair is likewise present in all animals and in plants as well.

---

[1] While it is true that icicles and other crystals apparently grow, this kind of growth is brought about wholly by the addition of material to the outer surface.

4. Reproduction of Living Things. — A third characteristic that distinguishes living things from those that are lifeless is the fact that they produce *seeds* (in the case of plants) or *eggs* (in the case of animals), which in turn come to form plants or animals like those by which these seeds or eggs were produced. No lifeless object can do this. We shall find in our laboratory study that, while there are a great many different methods of producing these new organisms, still in their essential features these various methods of reproduction are much the same from the lowest plants to the highest animals.

5. Summary. — In brief, then, we may say that *all living things have the power of growth from within, of self-repair, and of the reproduction of their kind;* but that so far as we know lifeless objects possess none of these powers.

6. Science and its Subdivisions. — Ever since the dawn of history we find that mankind has been seeking to learn the secrets of living and lifeless matter. During the past century our knowledge has increased so rapidly that many sciences have been completely rewritten. The discoveries, for example, of the characteristics of radium and of X-rays have revolutionized much of what was formerly believed as to the properties of lifeless matter. In the same way our increased knowledge regarding germs and other microscopic plants and animals has made possible the scientific treatment of disease, and what is more important, the prevention of disease. As our knowledge of the living and lifeless world has increased, it has become necessary to divide this knowledge into a great many different branches, some of which are physics, chemistry, geology (a study of the earth), mathematics, psychology (a study of mind), and biology.

7. **Biology** (from Greek, *bi'os* = life + *lo'gos* = discourse) is the general name given to the study of all living things. Hence, this science treats of both animals and plants. If we confine our study to the structure and activities of plants alone, we call this part of the science *plant biology*, or *botany*. *Animal biology*, or *zoölogy*, on the other hand, treats of animals. So-called *human physiology* (better known as *human biology*) discusses man, the highest type of the animal kingdom; hence, it is a branch of the science of zoölogy, which in turn is one of the subdivisions of the study of biology.

CHAPTER II

COMPOSITION OF LIFELESS AND LIVING THINGS

8. Introduction. — For a great many years scientists have been studying plants and animals, and from this study they have learned that the bodies of all living organisms, including human beings, are made from substances found in the water, soil, and air, and that when plants and animals cease to live, their bodies are changed into the chemical substances of which soil, air, and water are composed. We are now to learn by experiments the characteristics of some of these materials found in lifeless things, and some of the combinations of these materials in plants and animals.

I. ELEMENTS, COMPOUNDS, AND OXIDATION

Materials: Splinters of wood and pieces of carbon; starch, sugar, egg, meat; potassium chlorate, oxid of manganese, pieces of marble, zinc, hydrochloric acid, lime water (see below); elements for demonstration (*e.g.* phosphorus, sulphur, iron, magnesium); compounds for demonstration (*e.g.* magnesium sulphate, sodium nitrate, potassium nitrate, calcium phosphate, calcium carbonate); test tubes, thistle tube, apparatus stand, tray for collecting gases, delivery tube, cylindrical graduate or glass jar. (All of the materials named above will be found in the chemical or physical laboratory of almost every high school.)

Preparation of lime water: Put into a large bottle a good handful of lime (freshly slaked in water, if possible; air-slaked lime may be used, however). Fill the bottle with water, shake the mixture, and allow it to stand until needed. Then pour some of the liquid through a funnel in which is a filter paper. Collect the filtered lime water in a bottle, and keep it stoppered. As soon as it becomes cloudy, throw it away and obtain some more clear liquid by filtration as directed above. The large bottle can be kept indefinitely as a stock solution if it is kept filled with water.

9. Carbon (symbol, C). — Laboratory Study No. 1. Suggested as home work.

1. Prepare some charcoal by lighting a long splinter of wood or a match and then blowing out the flame. (Prepared charcoal may be used.) Charcoal is nearly pure carbon.
   - *a.* Tell what you have done.
   - *b.* Is carbon (charcoal) a solid, a liquid, or a gas? What is its color?
   - *c.* Of what substance does this experiment prove that wood is partly composed?
2. Hold the tip of the carbon (charcoal) in a hot flame.
   - *a.* State what was done.
   - *b.* Does any of the carbon disappear?
   - *c.* Will carbon burn? How do you know?
3. State three characteristics of carbon (charcoal) that you have learned from these experiments.
4. Hold your hand over the glowing charcoal with your eyes closed. How can you still tell that the carbon is burning?

10. Oxygen (symbol, O). — Laboratory Study No. 2. Demonstration.

Preparation of oxygen: Thoroughly mix a teaspoonful of potassium chlorate with about one-fourth as much black oxid of manganese. Put the mixture in a large test tube. Close the mouth of the test tube with a stopper through which passes a delivery tube, the other end of which runs beneath the surface of water in a tray. Support the test tube in a slanting position on an apparatus stand, and heat the mixture gently with a gas or an alcohol flame, until the oxygen begins to be given off. Fill three or four bottles with water, cover each with a piece of glass or cardboard, and invert the first one over the mouth of the delivery tube, removing the cover when the mouth is under water. Continue to heat the mixture until the bottle is full of oxygen, then cover it under water with the glass plate or cardboard, and stand it right side up on the table. In the same way fill as many jars as are needed for the experiments with oxygen. (Fig. 1.)

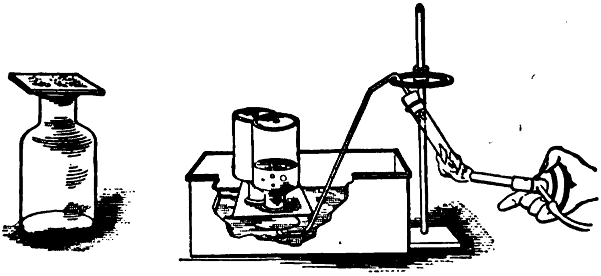

FIG. 1. — Preparation of oxygen.

Prepare several bottles of oxygen as directed and allow them to stand until all fumes have settled, before answering the following questions.

1. Examine a bottle of oxygen.
   a. State what you have done.
   b. Do you find oxygen to be a solid, a liquid, or a gas?
   c. State whether or not oxygen has color.
2. Heat some charcoal (carbon) till it glows and thrust it into a bottle of oxygen.
   a. Tell what was done and describe what happens.
   b. Does carbon burn better in air (which is a mixture of oxygen and other gases) or in pure oxygen?
3. State the three characteristics of oxygen which you have learned.

11. Carbon dioxid (formula, CO_2). — Laboratory Study No. 3. Demonstration.

Preparation of carbon dioxid: Into a flask put some piece of marble, and insert a stopper through which passes a thistl tube and a delivery tube like that used in the preparation of oxygen. Pour into the thistle tube diluted hydrochloric acid until the lower end of this tube is covered. Collect a bottle of carbon dioxid in the same way that oxygen is collected, keeping the mouth of the bottle closed with a glass plate or cardboard. (Fig. 2.) Prepare a bottle of carbon dioxid as directed, and allow it to stand till all fumes have disappeared, before answering the following questions.

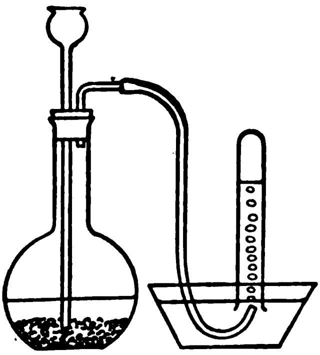

FIG. 2. — Preparation of carbon dioxid or of hydrogen.

1. Examine a bottle of carbon dioxid and state whether it is a solid, a liquid, or a gas. Compare this gas and oxygen as to color.
2. Light a splinter of wood and thrust it into the bottle of carbon dioxid.
   - *a.* Tell what was done and describe the effect of the carbon dioxid upon the burning splinter.
   - *b.* How was the burning splinter or carbon affected by oxygen?
3. Generate some carbon dioxid as suggested above and pass it through the delivery tube into a test tube of clear lime water. Tell what was done and describe the effect of carbon dioxid on lime water. (Carbon dioxid is the only gas that affects lime water in this way; hence the latter is a reliable test for carbon dioxid.)
4. State the four characteristics of carbon dioxid which you have learned from these experiments.
5. Place in a bottle of pure oxygen a piece of glowing carbon, and allow it to burn as long as it will. When the carbon ceases to burn, quickly remove

it, and pour in some clear lime water, cork the bottle, and shake.

a. Tell what was done and describe the change that takes place in the lime water.

b. What substance is evidently formed when carbon burns in oxygen?

6. When carbon is burned in oxygen, the two unite to form a new substance entirely different from either carbon or oxygen. This new substance is called carbon dioxid, because it is composed of one part of carbon and two of oxgyen.

a. State the composition of carbon dioxid.

b. Describe the method by which carbon dioxid was produced in 5, above.

7. (Optional.) By means of a glass tube blow the breath from the lungs into a test tube of lime water.

a. Describe this experiment and the change in the lime water.

b. What do you therefore conclude to be contained in the breath from the lungs?

12. Hydrogen (symbol, H) and water (formula, H_2O). — Laboratory Study No. 4. Demonstration.

Preparation of hydrogen (see Caution below): Into a flask put some pieces of zinc. (See Fig. 2.) Insert a stopper with two holes. Through one of the holes pass the lower end of a thistle tube until it nearly touches the bottom of the test tube, and through the other run a short piece of glass tubing. To the upper end of the latter attach by means of a piece of rubber tubing a delivery tube that will reach beneath the surface of a tray of water such as that used in collecting oxygen and in the preparation of carbon dioxid. Pour through the thistle tube enough diluted hydrochloric acid to cover the lower end of the thistle tube. (If hydrogen does not come off rapidly enough, put into the flask a bit of copper sulphate.) After the hydrogen has been given off for several minutes, collect a bottle over water in the same manner as in the oxygen experiment. Remove the bottle, holding it upside down, and place it on the desk in this position. Allow the bottle to stand till fumes disappear.

Caution: If in 3 below an explosion occurs, collect another bottle of hydrogen before answering the questions, for an explosion indicates that oxygen is mixed with the hydrogen, and such a mixture is dangerous to experiment with.

1. Examine a bottle of hydrogen, and state whether hydrogen is a solid, a liquid, or a gas. Compare its color with that of oxygen and carbon dioxid.
2. Thrust a lighted stick up into the mouth of an inverted bottle of hydrogen. (This experiment will be more satisfactory if the room is darkened.)
   a. State what was done and tell how the hydrogen affected the burning stick.
   b. How does the burning stick affect the hydrogen?
   c. What is one difference between oxygen and hydrogen?
   d. What is one difference between hydrogen and carbon dioxid?
3. If hydrogen is not being given off from the delivery tube in sufficient quantity, pour into the thistle tube some hydrochloric acid. Detach the delivery tube from the rubber tube of the hydrogen apparatus and insert in its place a piece of glass tubing, the upper end of which is drawn out to a small diameter. Collect some of the gas in a test tube by displacement of air and light it. When it burns with only a slight puff, apply a lighted match to the hydrogen escaping from the drawn-out tube.
   Hold over the flame a bottle which is clean and dry.
   a. Describe the preparation of this experiment.
   b. What do you find on the inside of the glass?
   c. What, therefore, is formed when hydrogen burns?
4. When hydrogen burns, it unites with the oxygen of the air and forms oxid of hydrogen, more commonly known as water (formula, H_2O).
   a. In what respect does hydrogen differ from oxid of hydrogen (water) in its most common form?
   b. State how oxid of hydrogen was formed.
   c. In what respects is the method of producing oxid of hydrogen (water) the same as that of producing oxide of carbon (carbon dioxid)? (See **11**, 5 above.)
5. Name five characteristics of hydrogen.

13. Nitrogen (symbol, N) and the composition of the air. — Laboratory Study No. 5. Demonstration.

Fasten a candle to a piece of cardboard and float the latter on a tray of lime water. Light the candle, and cover the flame with an inverted wide-mouthed bottle, bringing the latter slowly down until the edge rests on the bottom of the tray. Allow the candle to burn as long as it will. Then turn the bottle right side up, covering the mouth with the cardboard, keeping inside the bottle the lime water that has risen to take the place of the oxygen. Shake the contents of the bottle, to make the lime water absorb the carbon dioxid, and allow it to stand till the upper part of the jar is clear. Keep the bottle covered to prevent the mixing of air with the nitrogen.

1. Examine a bottle of nitrogen. Is it a solid, a liquid, or a gas? What is its color?
2. Thrust a burning splinter of wood into the nitrogen.
   - *a.* Tell what was done. Does the wood continue to burn?
   - *b.* Does the nitrogen burn?
   - *c.* In what respect does nitrogen differ from oxygen?
3. State four characteristics of nitrogen.
4. Why does carbon burn faster in oxygen than in air?
5. Air consists principally of oxygen and nitrogen. The water in the bottle represents the amount of oxygen there was in the bottle of air, and the nitrogen occupies the rest of the space.
   - *a.* About what fractional part of the air in the bottle was oxygen?
   - *b.* What fractional part of the air in the bottle is nitrogen?
6. Expose to the air of the room for a half hour or more a dish with some clear lime water.
   - *a.* Describe the experiment, stating the effect on the lime water.
   - *b.* What substance does this experiment prove to be present in air?

II. DEFINITIONS

14. A chemical element is a substance that has never been separated into two or more different kinds of matter.[1] — Over seventy of these elements are known at the present time, and of these seventy, twelve are found constantly in the living substance of plants and animals. The most common of these twelve elements are carbon (symbol, C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S), phosphorus (P), iron (Fe), and calcium (Ca), which is found in lime.

[In addition to the elements already studied (C, O, H, N), the others mentioned should be shown to students; and if time permits, some of these elements may be burned or oxidized in oxygen and the characteristics of the oxids thereby formed may be discussed.]

15. A chemical compound is a substance formed by the union of two or more chemical elements. — Two of the important compounds considered in biology are carbon dioxid (formula CO_2), which means that it is composed of one part of carbon and two parts of oxygen, and water (formula H_2O), which means that it is composed of two parts of hydrogen and one part of oxygen.

16. A mixture differs from a compound in the fact that the elements or compounds of which the former is composed are not chemically united. — In air, for instance, the oxygen and nitrogen are not chemically combined, but are simply put together as one might mix pepper and salt. Again, when sugar is dissolved or mixed with water, the two compounds are mingled so closely that the sugar disappears; it may easily be obtained unchanged in its composition by evaporating the water.

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[1] There are, however, exceptions to this statement, but they are too technical for discussion in an elementary text-book.

17. Oxidation is the chemical union of oxygen with some other substance. — It may take place slowly, as when carbon is made to glow in the air; or it may take place rapidly, as when carbon burns in oxygen. But whenever oxidation takes place, (1) an oxid is formed, (2) a certain amount of heat is liberated, and (3) if the process is sufficiently rapid, light is seen.

III. A STUDY OF THE FOOD SUBSTANCES

18. Introduction. — The food substances needed by plants and animals may be divided into five classes, namely: (1) *carbohydrates* (*i.e.* starches and sugars); (2) *fats and oils;* (3) *proteins*,[1] which are also known as albuminous or nitrogenous substances (*e.g.*, white of egg, lean meat, gluten of wheat); (4) *minerals* (*e.g.* common salt, saltpeter, phosphate of lime); (5) *water.*

19. To determine the chemical composition of starch. — Laboratory Study No. 6. Suggested as home work.

Warm some starch in an old cooking spoon in order to drive off any water that may be in it, but do not allow it to burn. To determine when the starch is free from water, hold the heated starch under a dry, cold tumbler, and if no moisture collects upon the tumbler, the starch contains no water. Now set the starch on fire, and hold a cold, dry glass over the burning starch.

1. Tell what you have done and state what is formed on the inside of the tumbler by the burning of the starch.
2. What is the only chemical element that could possibly form water by burning (*i.e.* by uniting with oxygen)?
3. What chemical element, therefore, must have been present in the starch in order to have produced water when dry starch is burned?

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[1] The term *protein* is used throughout this book instead of *proteid*, because of the unanimous recommendation in favor of the former term by the American Society of Biological Chemists and the American Physiological Society. See *Science*, April 3, 1908.

4. What substance is left in the cooking spoon after the flame goes out?
5. Name two chemical elements proved to be present in starch.
6. Starch also contains oxygen. Name now the three chemical elements of which this nutrient is composed.

20. To determine the chemical composition of sugar, fat, and protein. — Laboratory Study No. 7. (Optional.)

1. Test sugar in the same way as directed in Laboratory Study No. 6, 1–5 (above).
   a. Describe each of the experiments, giving results and conclusions.
   b. Sugar, like starch, has oxygen also in its composition. Name now all the chemical elements of which sugar is composed.
2. In a similar way test a fat (*e.g.* lard, or the fat of meat).
   a. State what you do, what you see, and what you conclude.
   b. Fat, like starch and sugar, has oxygen in its composition, but in a different proportion. State, therefore, the three elements present in fat.
3. (Demonstration.) Secure a vegetable protein (*e.g.* gluten) and test it as directed above.
   a. Describe your experiments and give your results and conclusions.
   b. Besides the two elements you have shown to be present, protein also contains oxygen, nitrogen, sulphur, phosphorus, and often other elements. State, now, the chemical elements of which this food substance is composed.

21. Summary. — The carbohydrates, as we have learned and as their name implies, are composed of the chemical elements carbon, hydrogen, and oxygen. The same three chemical elements are likewise present in fats and proteins, but in different proportions. Proteins, however, in addition to the carbon, hydrogen, and oxygen, contain at least three other chemical elements, namely, nitrogen, sulphur, and phosphorus; in fact, proteins are the most complex of all chemical substances known.

Following is the composition of the various nutrients studied thus far: —

Starch, composed of C, H, O (in the proportion of $C_6H_{10}O_5$).

Sugar, composed of C, H, O. (Grape sugar = $C_6H_{12}O_6$.)

Fat, composed of C, H, O.

Protein, composed of C, H, O, N, S, P (and sometimes of other elements).

22. Tests for the food substances. — Having demonstrated that the various food substances are chemical compounds, each composed of several chemical elements, we are now to carry on experiments by which it will be possible to test for each of these food substances. By this means we shall be able to prove the presence or absence of starch, grape sugar, protein, fat, mineral matters, and water in the foods used by plants, animals, and man.

23. To test foods for starch. Laboratory Study No. 8.

Materials: Corn starch, grape sugar, white of egg, fat or oil, salt, water; various foods in the home kitchen; iodine solution (see below); test tubes; gas burner or alcohol lamp.

Preparation of iodine solution: A quart (1000 cc.) of iodine solution is made by dissolving in 5 teaspoonfuls (40 cc.) of water, one-half teaspoonful (4 grams) of potassium iodide, and one-fourth this amount of iodine (1 gram). This solution, when thoroughly mixed, should be diluted to make one quart (1000 cc.). In a clean bottle this mixture will keep indefinitely.[1]

1. Put a small amount (size of a pinhead) of corn starch in a test tube, add water, shake the mixture, and boil it over a gas flame. Pour into the starch mixture

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[1] From Peabody's "Laboratory Exercises." Henry Holt & Co.

thus formed a few drops of iodine. Describe the experiment, and state what color is produced.

2. Try the effect of iodine on each of the other food substances as follows: Put a small amount of grape sugar into a test tube; into a second tube put some white of egg (protein); into a third some fat or oil; into a fourth some mineral matter (salt); and into a fifth some water. Add a little water to each and boil as in 1 above to cook each nutrient. Add a drop or two of iodine solution to each test tube. Tell what happens.

Do any of the colors thus produced resemble at all the color resulting from the addition of iodine to starch?

3. From the preceding, state how you can determine whether or not a substance contains starch.

4. (Optional home work.) Test as many foods as you can (*e.g.* oatmeal, flour, raw meat, milk, parsnip, potato, onions, apples, beans, rice, pepper) in the following way: Put a small amount of a given food into a test tube or in a sauce pan, add a little water, and boil to cook each food, then add a few drops of iodine. Before making each test make sure that the test tube or saucer is clean. Prepare in your note-book a table like the following, and fill in under each head the names of the foods you have proved to contain or to be without starch.

STARCH PRESENT	STARCH ABSENT

24. To test foods for grape sugar. Laboratory Study No. 9.

Materials: Grape sugar, corn starch, white of egg, fat or oil, salt, water; various food substances common in home kitchen; Fehling's solution (see below); test tubes, gas burner or alcohol lamp.

Preparation of Fehling's Solution: — To make Fehling's solution dissolve 3 teaspoonfuls (34.64 grams) of pure pulverized copper sulphate (blue vitriol) in a little less than a half-pint of water (200 cc.). Make a second solution by dissolving in a pint (500 cc.) of water twelve heaping teaspoonfuls (150 grams) of Rochelle salt and 3 (5-inch) sticks of caustic soda (50 grams). Fehling's solution does not keep for any great length of time, and hence must be made up fresh a short time before it is needed. To do this, thoroughly mix two volumes of the copper sulphate solution and five volumes of the solution of Rochelle salt and caustic soda, and dilute the mixture with an equal volume of water. It is more convenient to prepare it in small quantities from the tablets that may be obtained of druggists. Before making any tests boil a small quantity of the Fehling's solution in a clean test tube. If it retains its transparent blue color, it is ready for use; otherwise a fresh supply must be prepared.[1]

1. Dissolve a small amount of grape sugar (glucose) in water in a test tube. Add some Fehling's solution and boil. Describe the experiment and the change in color.
2. Try the effect of Fehling's solution on each of the other food substances as follows: Put a small amount of starch into a test tube; into a second tube some white of egg; into a third tube some fat or oil; into a fourth tube some mineral matter (salt); and into a fifth tube some water. Add a little water to each tube, then pour in a small amount of Fehling's solution and boil as in 1 above. Do any of the colors produced resemble at all the color of the Fehling's solution when it was boiled with grape sugar?
3. From the preceding experiments state how you can determine whether or not a substance contains grape sugar.
4. (Optional.) Test as many foods as you can (*e.g.* onions, grapes, pears, granulated sugar, honey, molasses, parsnip, raw meat, milk, egg) in the following manner: Put a small amount of a given food into a test tube, add a little water, and a

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[1] From Peabody's "Laboratory Exercises." Henry Holt & Co., New York.

small spoonful of Fehling's solution, and boil. Before making each test make sure that the test tube is clean. Prepare in your note-book a table like the following, and fill in under each head the names of the foods you have proved to contain or to be without grape sugar.

Grape Sugar Present	Grape Sugar Absent

25. To test foods for proteins (albuminous or nitrogenous substances). — Laboratory Study No. 10.

Materials: White of egg, corn starch, grape sugar, mutton tallow or other fat, salt, water; piece of meat, milk; concentrated nitric acid, ammonia; test tubes; gas or alcohol lamp.

1. Pour a little concentrated nitric acid on a piece of hard boiled egg in a test tube.
   a. Describe the experiment and the change in color.
   b. (Optional.) Wash the egg with water, add a little concentrated ammonia, and note result.
2. Try the effect of nitric acid on each of the other food substances as follows: Put a small amount of starch into a test tube; into a second tube some grape sugar; into a third some mutton tallow or other fat; into a fourth some mineral matter (salt); and into a fifth tube some water. Add a little concentrated nitric acid to each of these foods. Is any color produced like that resulting from adding nitric acid to protein? (In case a liquid is to be tested with nitric acid, the mixture should be boiled before deciding whether protein is present or absent.)
3. From the preceding experiments state how you can determine whether or not a food contains protein.

4. (Optional.) Prepare in your note-book a table like the following, and place in the proper columns the names of the foods tested in class.

PROTEIN PRESENT	PROTEIN ABSENT

26. To test foods for fats. — Laboratory Study No. 11. Suggested as home work.

Materials: Butter or olive oil, corn starch, grape sugar, piece of boiled white of egg, salt, water; various foods in the home kitchen, including nuts.

1. Put on a piece of paper a piece of butter half the size of a pea (or a drop of olive oil). Put the paper in a warm place (*e.g.* in a hot oven or over a heated radiator) for a few moments, then hold the paper between yourself and the light. Describe what you have done, and state the effect of the fat on the paper.
2. Try the effect of each of the other food substances (starch, grape sugar, piece of boiled egg, *i.e.* protein, salt, *i.e.* mineral matter, water) on paper, by adding an equal quantity (half the size of a pea) of each to separate pieces of paper. Put the pieces of paper in a warm place as in 1 above. Hold each piece between yourself and the light. State what you have done. Do any of these food substances affect the paper as did the fat?
3. From the preceding experiments state how you can determine whether or not a food contains fat.

4. (Optional.) Prepare in your note-book a table like the following, and place in the proper columns the names of the foods tested at home or in class.

FAT PRESENT	FAT ABSENT

NOTE. In case a food which is being tested may possibly contain a small amount of fat, the food should be pulverized, shaken in a test tube with ether or benzine (to dissolve out the fat), and allowed to stand for 24 hours. The clear liquid should then be poured upon paper, and the ether or benzine allowed to evaporate.

Caution. Never handle ether or benzine near a flame or hot stove, since the vapor of these substances is very inflammable.

27. To test foods for mineral matter. Laboratory Study No. 12. Demonstration.

Materials: Salt, corn starch, grape sugar, piece of boiled egg, butter or fat, water.

1. Place a piece of salt half the size of a pea on an old cooking spoon and heat over as hot a flame as possible. Does the salt burn? Does it disappear?
2. In the same manner try the effect of heat on the other food substances (starch, grape sugar, white of egg, fat, water). Do any of these substances burn or disappear?
3. From the preceding experiments state how you can determine whether or not a food contains mineral matter.
4. (Optional home work.) Test at home in the same manner as described in 1 above a match stick and a leaf. Do these plant materials contain mineral matters? How do you know?

28. To test foods for water. — Laboratory Study No. 13. Home work.

1. Warm a little water on a spoon and place over it a dry, cool, tumbler. What do you see on the inside of the glass? How, then, can you tell whether or not water is found in a given food?

2. (Optional.) Test as many foods as you can by warming in turn a small quantity of each in a spoon (without letting the food burn), and holding over the spoon a dry, cool tumbler. What do you learn as to the presence of water in foods?
3. (Optional Demonstration.) *To determine the amount of water in potatoes:*
   a. Remove a thin layer of peel from a potato, weigh the potato, and lay it aside in a warm dry place (protected from mice). Weigh each day, and fill out in your note-book for each day the first, third, and fifth columns in a table like the following:

	Weight of Potato		Loss of Original Wt.		Per Cent of Loss	
	Without Peel	With Peel	Without Peel	With Peel	Without Peel	With Peel
First day	——	——	——	——	——	——
Second day	——	——	——	——	——	——
Third day	——	——	——	——	——	——
Fourth day	——	——	——	——	——	——
etc.						

   b. Secure a second potato about the same size as the first, weigh it each day, and place it beside the potato that was peeled. Record results and percentages for each day in second, fourth, and sixth columns of preceding table.
   c. Which of the two potatoes decreases in weight the more rapidly? Almost all the loss of weight is due to the evaporation of water; what do you infer, therefore, as to one use of the peel?
   d. Continue to weigh the potato without the peel at intervals until there is no further loss. What percentage of potato is water? When potatoes are bought at $3 per barrel, how much of this sum is paid for water?

IV. MANUFACTURE OF THE FOOD SUBSTANCES BY PLANTS

29. Is starch present in the green leaves of a plant that has been exposed to sunlight? — Laboratory Study No. 14.

Take several leaves from a vigorous plant (*e.g.* geranium, hydrangea) which has been exposed to bright sunlight for a number of hours. Boil them a few moments in a large test tube or flask of water; pour off the water, add alcohol, and boil carefully over a piece of wire gauze or asbestos until all the green coloring matter has been removed. Rinse the leaves in water, add iodine solution, and spread the leaves on saucers, or in Petri dishes.

1. Describe in your own words how the experiment was performed.
2. Is starch present in the leaves? How do you know?
3. Why was it necessary to remove the green coloring matter from the leaves before testing for starch? (If you are in doubt, add some iodine to green leaves.)

4. (Optional.) How may grass stains be removed from clothing?

30. Is starch present in the green leaves of a plant that has been deprived of sunlight?[1] — Laboratory Study No. 15.

Put a vigorous plant (*e.g.* fuchsia, squash, sunflower, or bean seedling) in darkness for 48 hours or more. Remove several leaves, and treat them as described in **29** above.

1. State briefly how the preparation of this experiment differs from that in the previous experiment.
2. Give your observation and conclusion.
3. State, therefore, whether sunlight is or is not necessary for the manufacture of starch in green leaves.

31. Is starch present in colorless portions of green leaves? — Laboratory Study No. 16.

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[1] A most suggestive series of experiments on the formation of starch in green leaves is found in the *Botanical Gazette* for September, 1909, pp. 224–228, by Sophia Eckerson, of Smith College.

Secure a plant having some portions that are colorless (*e.g.* striped grass). Expose the plant to sunlight for two or three hours, then remove several leaves and test them in the same manner as described in **29** above.

1. State briefly how the preparation of this experiment differs from that of the two preceding experiments.
2. What is your observation and conclusion as to the presence of the starch in the green and colorless portions?
3. State, therefore, whether green material is or is not necessary for the manufacture of starch.

This green material in leaves is called *chlorophyll* (from Greek *chloros* = green + *phullon* = leaf).

32. Is carbon dioxid necessary for starch manufacture in leaves? — Laboratory Study No. 17.

Secure two vigorous potted plants, two bell-jars large enough to go over the plant and pot, and two trays or other receptacles having a greater diameter than that of the bell-jar. Place the plants in darkness for 24 hours at least, so that the leaves may be free from starch (see **30** above). Now test the leaves of both plants to make sure they are free from starch. Into one tray pour a quantity of lime water and into the other tap water. Put the plants on supports of some kind so that the pots will not touch the liquid, and cover with the bell-jars. (See Fig. 3.) Be sure that the edges of the bell-jars are covered with the liquid, so that no air can enter the jars. Place both preparations where the plants can get no sunlight for 24 hours in order to give time for the absorption of carbon dioxid in the jar with the lime water. Place both preparations in strong sunlight for several hours.

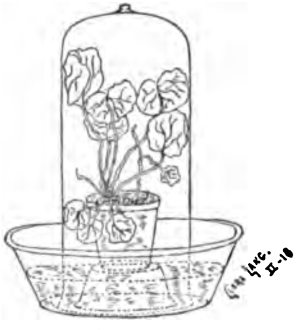

FIG. 3. — Apparatus for demonstrating the relation of carbon dioxid to starch manufacture.

1. Describe the preparation of the experiment.
2. Examine the lime water inside the bell-jar. What proof have you that carbon dioxid has been absorbed?
3. Remove a leaf from each of the plants and test for starch. Tell what was done and state your observations. Which leaf, therefore, contains starch?
4. What is your conclusion as to the necessity of carbon dioxid for starch manufacture?
5. What chemical elements that are present in starch might be furnished by the carbon dioxid (CO_2)?
6. The other raw material needed by plants for the manufacture of starch is water (H_2O). What third chemical element found in starch must be furnished by water?
7. Now name the two raw materials used by plants in the manufacture of starch and state the chemical elements which each can furnish.

33. Manufacture of carbohydrates. — The substance first made by the combination of carbon, hydrogen, and oxygen in the leaves is not starch, but a simple carbohydrate which is then made into grape sugar. When the plant manufactures more sugar than it needs for immediate use, the surplus is changed to starch, and this is what we have found stored in the leaves.

34. Manufacture of proteins. — We have already learned that proteins contain carbon, hydrogen, oxygen, nitrogen, and usually sulphur and phosphorus (see **21**). The plant, therefore, must somehow obtain these elements in order to manufacture proteins. It has been proved that plants manufacture sugar, and this probably supplies the necessary carbon, hydrogen, and oxygen. The nitrogen that is needed is furnished by compounds containing nitrogen such as saltpeter (potassium nitrate, KNO_3), and the sulphur and phosphorus are secured from mineral compounds known as sulphates and phosphates. These compounds are derived from soil water. From these compounds, namely, sugar and the mineral matters containing nitrogen, sulphur, and phosphorus obtained from the soil, the living plant manufactures protein.

35. Do green plants give off a gas in sunlight? — Laboratory Study No. 18.

Into a glass cylinder containing water fresh from the faucet put a small amount of water plant (Elodea, Spirogyra, or Milfoil), holding it to the bottom of the tall jar by means of a weight if necessary. Stand the cylinder in direct sunlight.

1. Describe the preparation of the experiment.
2. What do you observe coming off from the plant? (These bubbles of gas have been proved to be composed of oxygen.)

36. Do green plants give off a gas when deprived of sunlight? — Laboratory Study No. 19.

Place the glass cylinder prepared as directed above in darkness for several hours (or, still better, a second cylinder should be used for comparison).

1. In what respects do Experiments 18 and 19 differ?
2. Do you see any bubbles as long as the cylinder is kept in the dark?
3. Under what condition, therefore, does a green plant give off oxygen?

37. The oxygen supply for animals. — We have seen that starch is made of carbon dioxid (CO_2) and water (H_2O). By repeated experiments biologists have proved that in the process of manufacturing carbohydrates more oxygen is present in the CO_2 and H_2O than is needed. This is the oxygen we have seen given off by the green water plant in sunlight. Every green plant gives off oxygen into the air when manufacturing carbohydrates. Hence, in this process the carbon dioxid is constantly being taken from the air and a fresh supply of oxygen set free.

CHAPTER III

THE STRUCTURE OF PLANTS

38. The parts of a plant. — Laboratory Study No. 20.

Materials: **A well-developed bean plant or other seedling or a weed, for each two pupils; one or more plants with flowers and if possible with fruits for demonstration.**

Nearly all the plants with which we are most familiar consist of at least three kinds of parts, namely, *roots, stems,* and *leaves* (Fig. 4).

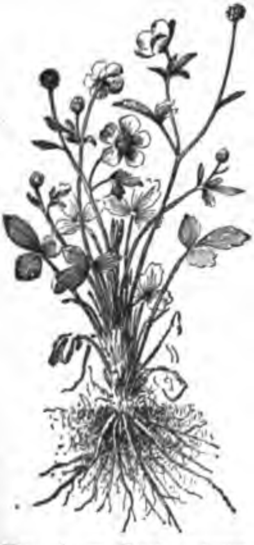

FIG. 4. — Roots, stems, leaves, flowers, and fruits of a buttercup plant.

1. Name and describe as to color and form the parts of the plant that grew beneath the ground.
2. How does the stem differ from the root as to color and direction of growth? What parts of the plant above ground are attached to the stem?
3. How does the main part of the leaf differ in form from the root or the stem?
4. Make a drawing, natural size, of the plant you are studying, labeling ground level, roots, stem, leaf.
5. On the plants used for demonstration, what parts besides those named above do you find? How do the colors of these parts differ from the color of the rest of the plant?

39. Organs and functions. — From our laboratory study we have learned that a common plant consists of roots, stems, and leaves, and that at certain seasons of the year flowers and fruits are present. To each of these various parts is given the name *organ.* Roots are useful to a plant, for one thing, because they hold it in the ground, while stems support the leaves, flowers, and fruits. In fact every organ of a plant has some work to do, and this work is called its *function.* Hence, we may define an *organ as a part of a plant that has a certain function or functions to perform.*

40. Microscopic structure of plants. — When one examines by the aid of a compound microscope a small portion of any of the organs of common plants, one finds that each organ is composed of many smaller portions too minute to be seen with the unaided eye. These tiny divisions are called *cells.* We shall now attempt to become familiar by the use of the compound microscope with the appearance of several kinds of plant cells.

41. Study of plant cells. — Laboratory Study No. 21.

Materials: (1) Slides prepared as follows: Cut a layer of an onion bulb into small squares, and strip off from the inner surface of each square a very thin layer. Place it on a glass slide and add a drop of water. (If it is desirable to keep the slides for several hours, put glycerin diluted with water over the onion cells.) Cover each thin membrane with a cover glass.[1] (2) Prepared or freshly cut thin sections of roots, stems, and leaves.

1. By the aid of the low power of the compound microscope, examine the slide prepared as directed in (1) under materials. Note that the thin membrane is composed of a large number of tiny spaces each in-

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[1] The authors are indebted to Miss Elsie M. Kupfer, Head of Department of Biology of Wadleigh High School, New York City, for suggesting this admirable material for cell study.

closed by lines more or less dark in color called *cell-walls*. (These parts are usually seen more clearly if the light is largely excluded by closing the diaphragm in the stage.)

a. Describe the general appearance of the membrane, stating of what it is composed.

b. State whether or not the cells in the various parts of the membrane differ in size and shape.

2. Within the cell-body, often near the center of the cell, is usually a tiny object called the *nucleus*. Describe the location, shape, and color of the nucleus.

3. All the parts of the cell between the cell-wall and the nucleus constitute the *cell-body*. Describe the location and the appearance of the cell-body.

4. Make a drawing of three or four adjacent cells, several times as large as they appear under the microscope. Label cell-wall, cell-body, cell-nucleus.

5. (Demonstration.) Secure some growing sprays of Elodea (a common water plant). Pull off one of the youngest leaves near the tip end, put it on a slide with a drop of water, and cover with a cover glass. Let the preparation stand in a warm place for a time. Examine with the high power the cells of which this leaf is composed.

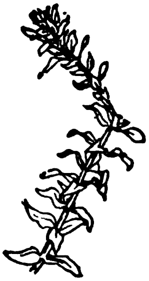

FIG. 5.—Elodea plant.

Within each cell note some green bodies called *chlorophyll bodies* (from Greek, meaning leaf green). These are the bodies which aid in starch manufacture in green leaves. (See **31**.)

a. Describe the form, color, and use of chlorophyll bodies.

b. Carefully watch the chlorophyll bodies in several cells and describe any movements you see. These movements show that the substance of the cell is in motion, and is carrying the chlorophyll bodies along with it.

c. Make a drawing at least 2 inches long of one of the cells with its chlorophyll bodies. Label cell-wall, chlorophyll bodies, and show by arrows the direction of their movements.

6. (Demonstration.) Examine with the low power of the microscope the sections of root, stem, and leaf, or study Figures 11, 12, 15, 22. What have you learned of the microscopic structure of root, stem, and leaf?

(Optional.) Make a drawing of four or five cells from each of the organs studied.

42. Cells and protoplasm. — Under the microscope cells at first appear to be only plane surfaces surrounded by lines. In reality, however, each cell has not only length and breadth, but also thickness, and each cell is covered on all sides by a cell-wall which is composed of a lifeless substance known as *cellulose.* This wall is often so transparent that we can look through it and see the cell-body and nucleus within (Fig. 6).

The discovery of these minute bodies of which organs are composed was not made until about the middle of the last century (1838). With the rather imperfect microscopes then in use the two discoverers, Schleiden and Schwann, could see the cell-walls only, and they did not know, as we now know, that the most important part of the cell is not the lifeless wall of cellulose, but the living substance which is found inside the cell-wall, making up a large part of the cell-body and cell-nucleus.

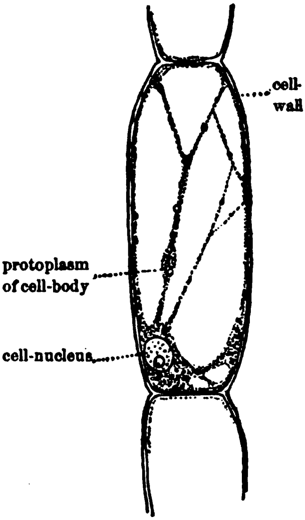

FIG. 6. — Plant cell. The spaces in the cell-body are filled with cell-sap.

To this substance is given the name *protoplasm.* We know now that the living substance or protoplasm is the essential part, while the wall may be missing, so that in such a case there is no resemblance to a cell or box. Biologists now understand *a cell to be a bit of protoplasm* (*cell-body*) *containing a nucleus* (which is a denser portion of the protoplasm).

Protoplasm, when examined with the highest powers of the microscope, appears as a colorless, semifluid substance, in which are often seen solid particles or granules, which are probably little masses of food. The nucleus, as already stated, is commonly found near the center of the cell, and is composed of protoplasm denser than the protoplasm of the body of the cell. The appearance and composition of the protoplasm may be well represented by raw white of egg; but in making this comparison one should bear in mind that the white of an egg is not living substance.

Within the cell, too, and occupying some of the space outside the nucleus, especially in plant cells, is *cell-sap*, which is a lifeless fluid composed of water in which are dissolved the food substances (such as sugar and mineral matters) used by cells in their growth and repair, and in the various kinds of work which they carry on (Fig. 6).

43. Assimilation, growth, and cell division. — To make protoplasm the plant must have proteins, water, and additional compounds containing iron, calcium, and several other chemical elements. But only protoplasm has the power to combine these compounds in such a way as to form living matter. Bearing in mind the facts we learned in studying food manufacture (**33** and **34**), we see that the plant begins with simple substances, water and carbon dioxid, and manufactures a more complex substance, sugar. It uses this and other substances to make a still more complex substance, protein, and finally ends by making the most complex of all, protoplasm. But, except in rare cases, all plants must have compounds to start with; they cannot make any of these nutrients or protoplasm from chemical elements.

And thus we learn that food materials are gradually changed by protoplasm into living substance like itself. To this process is given the name *assimilation* (Latin, *ad* = to = *similis* = like). As a result of the process of assimilation the amount of protoplasm of course increases and the cell grows. Were this process to continue indefinitely, cells would become large in size. This, however, does not occur; for when a cell reaches its normal size, the nucleus divides, and the halves separate from each other to form two nuclei. The cell-body now divides into two parts, and cell-walls are formed between the two cells (Fig. 7). Thus are produced two cells, each having its own nucleus, and these in turn assimilate, grow, and divide. In this way the number of cells increases with the growth of the plant.

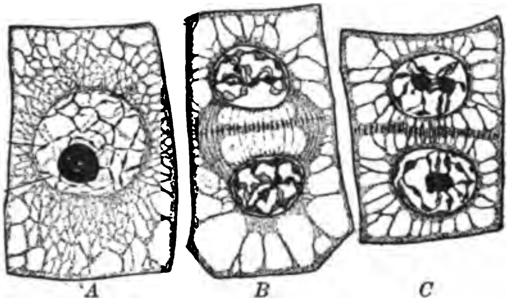

FIG. 7. — Cell division.

A, cell before division; *B*, cell with divided nucleus; *C*, single cell that has divided into two cells.

CHAPTER IV

OSMOSIS AND DIGESTION

Materials: Four thistle tubes, four wide-mouthed bottles; honey, molasses, or a thick solution of grape sugar; starch (arrowroot if possible), diastase; white of egg, peptone; iodine, Fehling's solution, nitric acid. Procure the intestines of calf or beef, wash them thoroughly inside and out, and inflate them by the aid of a glass tube. Tie at intervals of two or three feet, and allow this animal membrane to dry. Cut off pieces about two inches long, and slit open each of the pieces thus obtained. Membrane prepared in this way may be kept in closed bottles for years. If desired, the pieces of membrane may be used at once without drying. Sausage coverings preserved in salt may be thoroughly washed, dried, and used. This membrane is made of cells.

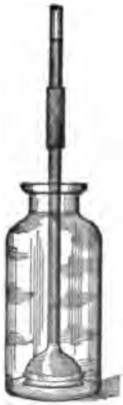

FIG. 8. — Apparatus for thistle tube No. 1 in osmosis experiment.

Thistle tube No. 1. — Hold one of the thistle tubes upright, closing the smaller end by pressing on it with the thumb. Into the larger end pour the honey, molasses, or grape sugar solution, which has been sufficiently warmed to pour easily. Half fill the tube and nearly fill the bulb. Moisten one of the pieces of intestine and tie it tightly over the bulb of the thistle tube so that none of the liquid can escape. Wash off any of the liquid from the outside of the membrane, then dry it with a blotter, and hold the thistle tube bulb down for several minutes to make sure that the grape sugar solution does not leak out. Now stand the tube, membrane down, in one of the wide-mouthed bottles and fill it with water up to the neck. Add grape sugar solution to the thistle tube until the level of the water in the bottle and that of the liquid in the thistle tube is the same. Connect a long piece of glass tubing to the upper end of the inverted thistle tube, and support this tube in a vertical position, so that the membrane does not touch the bottom of the bottle (Fig. 8).

Thistle tube No. 2. — Set up a control experiment exactly like No. 1, except that water should be put into the thistle tube as well as in the bottle.

44. Will water pass through a membrane (cell-walls)? — Laboratory Study No. 22.

1. Give in your own words a description of the way thistle tube No. 1 was prepared, making a diagram of the apparatus, and labeling level of water in bottle and of grape sugar solution in thistle tube at the beginning of the experiment.
2. At the end of a few hours compare the level of the liquid in thistle tube No. 1 with the level in thistle tube No. 2.
   - *a.* How many inches has the grape sugar risen in No. 1?
   - *b.* Is there a similar rise in the water in thistle tube No. 2?
   - *c.* What must have passed into thistle tube No. 1 to cause the liquid to rise?
   - *d.* Through what must this liquid have passed to get into the thistle tube?
3. Do you conclude, therefore, that water will or will not pass through a membrane?

45. Will grape sugar pass through a membrane (cell-walls)? — Laboratory Study No. 23.

1. At the end of a few hours test the liquid in bottle No. 1 by putting a glass tube to the bottom of the bottle, pressing the thumb over the top of the tube, and removing the sample of liquid thus obtained to a clean test tube; add Fehling's solution and boil.

  a. Describe what was done.
  b. Is grape sugar present now? How do you know?
  c. What must have happened to produce this result?

2. We have now proved that two different liquids have passed through the membrane.
    a. Name these two liquids.
    b. Which of these two liquids has passed through the membrane in the greater quantity? How do you know?
    c. Which of these two liquids is the thicker or denser?
    d. By a great many experiments it has been proved that, when any two liquids of different density are separated by a plant or animal membrane, results similar to those noted above follow. *To this interchange of liquids is given the name osmosis.* In this process of osmosis, is the greater flow of liquid from the less dense to the more dense, or from the more dense to the less dense?
    e. Why did not the water rise in thistle tube No. 2?
3. Do you conclude, therefore, that grape sugar will or will not pass through a membrane?

46. Osmosis in living cells. — Laboratory Study No. 24.

Peel a potato and then cut several cross sections about ⅛ inch in thickness. Allow these sections to stand in the air until they bend readily. Half fill one tumbler with water and a second tumbler with a strong solution of sugar or salt. Place some of the sections in each of the two tumblers and leave them for several hours.

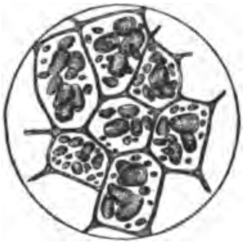

FIG. 9. — Cells from a potato, showing cell-walls, cell-sap, and starch grains of different sizes.

1. Describe the preparation of this experiment.
2. Remove a section of potato from each of the liquids and bend them. Compare the change that has taken place in the rigidity or stiffness of the sections placed in the strong solution and those in the tap water.

3. Potato sections, like those of all parts of living plants, are composed of a large number of living cells, each one inclosed by a cell membrane (Fig. 9).
   Call to mind what you learned in **45**, and state why the cells become more flabby in one solution and more rigid in the other.

47. Will starch pass through a membrane (cell-walls)? — Laboratory Study No. 25.

Thistle tube No. 3. — Put into a third thistle tube a mixture of starch and water, cover the bulb with a membrane, and invert in a bottle of water, as already directed for the first thistle tube. See that the level of the liquid is the same in all of the experiments.

1. In what respects does the preparation of thistle tube No 3 resemble that of No. 1? How do the two experiments differ?
2. At the end of a few hours test the liquid in bottle No. 3 by removing a sample to a test tube (as already directed in **45**), and adding iodine solution.
   - *a.* Is starch present? How do you know?
   - *b.* What is your conclusion as to the possibility of starch passing through a membrane?
3. What have these experiments in osmosis taught you as to one difference between starch and grape sugar?

48. Definitions and applications. — The experiments we have been performing have most important relations to the study of all living plants and animals. We may give the following as a definition of the process we are considering: *Osmosis is the interchange of liquids of different density that are separated by a plant or an animal membrane (cell-walls). In the process of osmosis the greater flow is always from the less dense liquid to the more dense.*

We shall constantly refer to this principle of osmosis, and we shall find that it explains in large measure the absorption of soil water by roots, the transfer of sap from one part of a plant to another, as well as the processes by which the blood of animals obtains and gives off food to various cells of the body.

By the preceding experiments we have proved that there are two classes of food substances. One kind (including water and grape sugar) will readily pass through a membrane by osmosis; the other kind (represented by starch) will not. In our study of cells we learned that the protoplasm or living substance is inclosed by a cell-wall which separates one cell from another. Now if cells are to make use of the food materials manufactured in other parts of the plant, each food substance must be in such a form that it can pass through these cell-membranes. It is evident that water and grape sugar can do this. We find, however, large quantities of starch stored in cells (Fig. 9). Hence, to be available for use in other cells, some change must be made in this food substance before it can be transferred from cell to cell. We shall now show by experiment what this change is.

49. How starch is made ready to pass through cell-walls. — Laboratory Study No. 26.

Into each of two test tubes put a small amount of starch (arrowroot starch if it can be obtained), add some water, shake, and boil. To the starch mixture in one test tube add some *diastase*, equal in amount to one-half the size of a pea. (Diastase is a chemical substance produced or secreted by the protoplasm of plant cells.) Put the two test tubes side by side in a warm place for 5 minutes if arrowroot starch, 24 hours if corn starch is used, then test a small amount of the mixture in each test tube by adding a few drops of iodine.

1. Describe in your own words what has been done.
2. In which test tube do you find starch present?
3. Now test with Fehling's solution a small quantity of each mixture. In which tube do you find grape sugar?

4. What do you conclude, therefore, as to the effect of diastase on starch?
5. Why is this change necessary if starch is to be used by plants?

50. To prove that starch is made soluble in growing plants. — Laboratory Study No. 27.

1. Pound two or three corn grains into a powder and put some of this corn meal into a test tube, add water, and boil. To one-half of the mixture add iodine, and to the other half, Fehling's solution, and boil. Give a careful description of the experiment and state your observations and conclusions.
2. Secure some germinating corn grains, cut them into small pieces, and test some of them with Fehling's solution as in 1 above. Describe the experiment, stating your observations and conclusions.
3. The change in starch that you have described is known as *digestion*. What reason have you for believing that starch is made soluble when corn grains germinate? This change in starch is known as *digestion*.

51. Definition of digestion. — We may define *digestion as the chemical change whereby insoluble food substances are made ready to pass through cell-walls or made ready to be used in cells*. Let us now by experiment determine whether or not protein needs digestion.

52. Will protein pass through a membrane (cell-walls)? — Laboratory Study No. 28.

Thistle tube No. 4. — Secure some white of egg, cut it with scissors and mix it with water. (White of egg, we found, contains a large amount of protein.) Prepare the fourth thistle tube in the same way as directed for thistle tube No. 1, only using white of egg and water instead of grape sugar. See that the level of the liquid is the same as in thistle tube No. 2.

1. In what respects does the preparation of thistle tube No. 4 resemble that of thistle tube No. 1? How do the two experiments differ?
2. Allow the experiment to stand for several hours, and then remove with a glass tube a sample of the liquid in bottle No. 4, and test it by adding nitric acid and boiling. Is protein present? How do you know?
3. Do you conclude, therefore, that protein will or will not pass through a membrane?

53. Digestive ferments. — We have stated that protoplasm secretes a substance called diastase, and have shown that this diastase will change insoluble starch to soluble grape sugar, which will pass from one cell to another by the process of osmosis, or be ready for use in the cells. Diastase is a substance known as a *digestive ferment*. Now protoplasm produces other digestive ferments, some of which will change proteins to soluble substances that will readily pass through cell-walls by the process of osmosis, and be in such a condition that it can be used by protoplasm.

Fats, also, like starch and protein, are insoluble and cannot, therefore, pass by osmosis through cell walls. To make these food substances available for use they must also be changed by the plant cells into such forms that they may be readily transferred from one part of the plant to another. These changes are caused by other chemical ferments produced by protoplasm.

CHAPTER V

ADAPTATIONS OF THE NUTRITIVE ORGANS OF PLANTS

54. The nutritive organs of plants. — From our study of food manufacture (**29–34**) we learned that the plant foods are produced in green leaves. Before this process of food manufacture can go on, however, the cells in the leaf must be supplied with raw materials from the air and from the soil. Since the roots, stems, and leaves are all concerned in food making, these organs are known as *the nutritive organs of plants*. Each of these organs has several functions; we shall now learn what some of these functions are, and how the nutritive organs are adapted for the work they do.

I. THE STRUCTURE AND ADAPTATIONS OF ROOTS

55. The structure of roots. — Laboratory Study No. 29.

A. Gross structure of roots.

Select the largest roots of a well-developed seedling or the roots of common weeds. By means of your thumb and finger nail gently scrape off the outer layers from a piece of one of these roots. When no more of the material can be easily removed by this method, pick to pieces the central part of the root which is left. The outer layer you have removed is largely composed of the cells of the *cortex*, and the central part that has been exposed is called the *central cylinder*.

1. Tell what you have done.
2. Which is composed of the tougher and harder material, the cortex or the central cylinder?

3. Make a diagram greatly enlarged of a piece of root prepared as directed above. Label cortex, central cylinder, fibers of central cylinder.

B. *Root-hairs.*

Note to the Teacher. — Root-hairs may be grown for study as follows: Cover the bottom of as many Petri dishes as are needed with a layer of blue blotting paper. Soak the paper with water and lay several grains of soaked barley, oats, or corn upon the bottom of each dish. Put the covered dishes in a warm place for several days. When the root-hairs have developed, wipe the moisture from the inside of the covers, quickly replacing the latter. If Petri dishes are not available, two clean glasses of any convenient size may be used instead. Cover one of the plates with layers of wet blotting paper, put the soaked grains in position, and cover with the second glass, fastening the two together with threads or strings. Stand one end of the preparation thus made in a jar with enough water to reach the lower edge of the blotting paper.

Examine first with the naked eye and then with a hand magnifier the roots of sprouted grains, developed as described above. Notice tiny outgrowths from the sides of the roots; these outgrowths are called *root-hairs.*

1. Look at the very tip of the root and state whether root hairs are there present or absent.
2. State whether the root-hairs are longest near the tip or in the direction of the grain.
3. Make a drawing much enlarged to show the shape of one of the roots including the root-tip and the various lengths of root-hairs. Label root-tip, root-hairs.

C. *Microscopical structure of the tip of a root.* (*Optional.*)

Examine with the aid of the low power of the compound microscope a root-tip mounted on a slide in drop of water and covered with a cover glass. Make a sketch very much enlarged to show —

1. The outline of the root including the tip.
2. A loose mass of cells covering the lower end of the root which make up the *root-cap*.
3. Label root-tip, cells of the root-cap.

56. The functions of roots. — Laboratory Study No. 30.

A. Roots as organs for holding the plant to the soil.

Secure a vigorously growing plant in a pot (*e.g.* a rubber plant) or better try the following experiment on a good sized weed in a field. Attach to the stem just above ground level a spring balance. Pull on the balance until the plant shows signs of letting go its hold on the soil, then note the reading in pounds on the scale.

1. In your own words describe what was done.
2. How much force in pounds was exerted on the plant?
3. What important function of roots is shown by this experiment?

B. Roots as organs for absorbing soil-water.

(Before proceeding further with the root study, the osmosis experiments, **44–53**, should be performed if they have not already been done.)

Study the diagram of a root-hair in the text-book (Fig. 12) and if possible examine with the low power of the microscope some of the younger (shorter) root-hairs. Each root-hair is an elongated part of an outer cell of the root.

1. Draw in your note-book a diagram of a root-hair, labeling cell-wall, thin layer of protoplasm, cell-sap, and nucleus.
2. What separates the soil-water from the cell-contents?
3. Recall the characteristics of cellular structure as given in **42**. Now state which is the more dense, the soil-water or the cell-contents.

4. In which direction, therefore, will there be the greater movement of liquid in the process of osmosis?
5. State several characteristics that adapt root-hairs for absorbing soil-water.

C. Roots as organs for transmitting soil-water.

Place some seedlings or weeds in red ink so that only the lower ends of the roots are in the liquid. Cut some cross sections of these roots above the point where they were in contact with the ink. Examine the cross section of the root prepared in this way.

1. Describe the experiment as it was performed.
2. Through what part of the root (cortex or central cylinder) has most of the liquid passed? How do you know?
3. Make a sketch about an inch in diameter of the cross section of the root, to show the colored and colorless portions. Label: part of the root through which liquid traveled, unstained portion of root, cortex, central cylinder.

D. Roots as organs for the storage of food.

Cut some slices about an inch thick from parsnips or other fleshy roots, and divide each slice vertically in halves. Put the pieces in water and boil for a few moments to partially cook them. Pour iodine solution over some of the pieces; to others add strong nitric acid; boil still other pieces in a test tube with Fehling's solution.

1. Describe the preparation of each of the experiments, and state in each case your observations.
2. What do you conclude as to the presence or absence of each of three of the food substances in various parts of the fleshy root you are studying?
3. What function of roots do these experiments demonstrate?

57. Adaptations of roots for holding to the soil. — One of the most obvious functions of roots is that of holding plants firmly in the ground. If the soil is carefully removed from the roots of a weed or a tree, these roots will be found to extend outward in all directions to a distance even greater than do the branches above ground. When one remembers the tremendous force exerted upon trees by high winds, the necessity for this extensive root anchorage will be evident. In our dissection of the root even of a young plant we found that the central cylinder was composed of tough fibers which are made up of elongated *wood-cells* (similar to those shown in Fig. 15). As a plant grows older, these central cylinders become so thick and tough that they will resist an enormous strain without breaking.

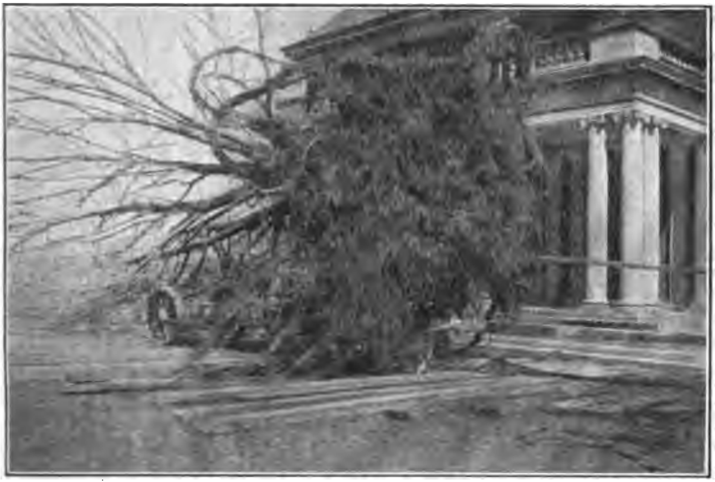

FIG. 10. — Roots of a tree, showing method of transplanting a large tree. (Courtesy of Isaac Hicks and Sons, Westbury, Long Island.)

58. Adaptations of roots for absorbing and transmitting soil-water. — A second function of roots we found to be that of absorbing soil-water and transmitting it to the stem. The whole outer surface of young roots is covered with a single layer of thin-walled cells which form the *epidermis*. Many of these cells develop tubular outgrowths known as root-hairs (see 56, B). By studying Fig. 12 it will be evident that each root-hair consists of a cell-wall lined by a thin layer of protoplasm. The interior of the cell is largely filled with cell-sap. On the outside of each root-hair is soil-water. All the conditions necessary for osmosis are therefore present. The cell-wall is the membrane which separates the soil-water from the denser cell-sap. From the law of osmosis, we should expect a flow of liquids in both directions, the greater flow being into the cell-sap from the soil-water. It has been found, however, that the

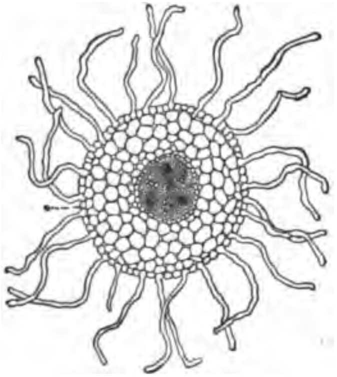

FIG. 11. — Cross section of root, showing root-hairs and epidermis cells on the outer surface, cells of cortex within, and woody central cylinder with its ducts. — (Bailey.)

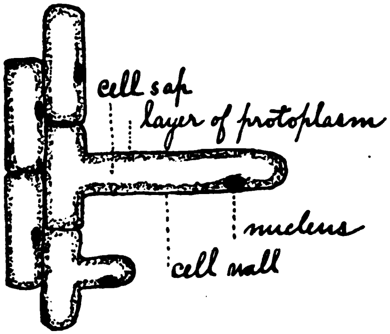

FIG. 12. — Diagram of a lengthwise section of two root-hairs with adjacent cells of the epidermis, and with two cells of the cortex.

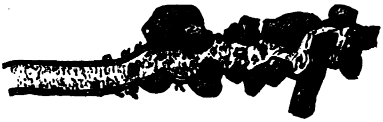

FIG. 13. — Portion of a root-hair with adhering particles of soil. — (Strasburger.)

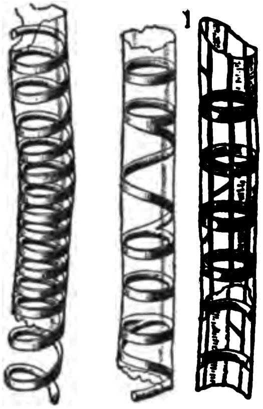

FIG. 14.— Ducts that convey the sap upward through the root, stems, and leaf. The walls of these ducts are strengthened by spiral fibers or rings.

protoplasm permits the inward flow of the soil-water, but practically prevents the outward flow of the cell-sap. Thus we see that protoplasm has a selective action. Since the growing parts of roots have countless root-hairs, these cells of the epidermis together act like a great sponge which absorbs the large quantities of water and mineral matters which are needed by all plants. This liquid passes from one cell to another until it reaches the central cylinder. A study of the microscopical structure of the central cylinder makes evident the fact that this part of the root consists not only of tough wood cells as explained in the preceding section, but also of tubular cells called *ducts.* (See Fig. 14.) Through these ducts the sap is conveyed upward to the stem.

II. THE STRUCTURE AND ADAPTATIONS OF STEMS

59. The structure of a woody stem. — Laboratory Study No. 31.

A. The structure of a young stem.

Secure pieces of a young stem of a horse-chestnut, maple, lilac, or other woody stem that shows the three layers of bark. Split some pieces lengthwise in halves.

1. Peel off the outer covering, the *bark,* from a piece of the stem till the wood is exposed. The bark of

a young stem usually consists of three more or less distinct layers.

a. With a knife gently scrape off an outer or *brown bark*, and expose a dark green layer known as the *green bark.* Scrape this until you come to a more or less tough layer known as the *fibrous bark* or *bast* (which may be slightly green). Describe each of these barks as to position and color.

b. Pick into threads the fibrous bark; in what direction of the stem do the fibers run? By breaking strips of each layer determine which of the three barks is toughest.

2. Feel of the wood from which the bark has just been removed. Describe the substance which covers the wood, after scraping off a little with your thumb nail. This is the *cambium* or *growing layer*, which produces the new wood and bark. When the bark is torn off, the cells of this layer are broken and the slimy protoplasm oozes out.
3. By means of a penknife or pin dig into the wood and also into the pith at the center of the stem. Compare the wood and the pith as to relative position and hardness.
4. By the aid of compasses make a diagram, at least three inches in diameter, of the cross section of a woody stem to show the relative thickness of the various layers. (These layers might well be represented by different colors.) Label brown bark, green bark, fibrous bark or bast, cambium layer, wood, pith.

B. The structure of an older stem. (Optional.)

Cut some cross sections of stems several years old. (Admirable material can be obtained by sawing into pieces about two inches long white oak sticks three to four inches in diameter.) Each piece should then be split into halves and each surface planed and sandpapered. These pieces are valuable as permanent preparations.

1. Which of the three regions (bark, wood, and pith) found in the young stem can you readily distinguish? Which of the three becomes very much thicker and harder as the stem grows older? Which is very small in quantity when compared with the young stem?
2. The curved layers of wood in the cross section are known as *annual rings*, so called because usually only one ring is formed each year by the cambium layer. How many years of growth are shown in the piece of wood you are studying?
3. The lines in the cross section extending like the spokes of a wheel are the *pith rays* or *medullary rays*. Describe the appearance of these rays. The shining, lighter colored surfaces (to which the beauty of "quartered oak" furniture is due), that appear in the longitudinal sections of oak wood, are the pith rays. Find pith rays in the middle surfaces of some of the oak pieces you are studying, and describe them.
4. Make a large diagram of the cross section of the piece of wood you are studying. Label bark, wood, annual rings, medullary or pith rays.

60. The structure of the corn stem.—Laboratory Study No. 32. (Optional.)

Cut pieces about two inches in length from full-grown corn stalks, and split each piece in halves. (If necessary these pieces may be preserved from year to year in 4 per cent formalin or in 70 per cent alcohol.)

Examine the cross and longitudinal sections of corn stem. Find the *rind* (the outer layer), the *woody bundles* or *fibers* (thread-like structures), and the *pith* (material between the bundles).

1. Thrust your pencil point into the pith; is this material hard or soft?
2. Pull out one of the woody fibers; is it tough or tender?
3. Push your pencil point into the rind; is it hard or soft?
4. Make a drawing (× 2) showing both cross and longitudinal surfaces. Label rind, woody bundles, pith.

61. Experiments to show the upward path of sap through stems. — Laboratory Study No. 33.

A. Stand some live twigs (*e.g.* maple or horse-chestnut) in red ink for a day or two; cut off pieces above the level of the ink, and split some of these pieces in half lengthwise.

1. Describe the preparation of the experiment.
2. Through what part of the stem does the red ink rise?
3. What do you conclude, therefore, as to the part of a woody stem through which sap rises?

B. (Optional.) Stand in red ink some pieces of fresh corn stalk (or if this cannot be obtained, some Tradescantia or any lily stem). Cut some cross and longitudinal sections above the level of the ink.

1. Write an account of the experiment, stating your observations.
2. In the stem you are studying, is sap carried upward by the rind (epidermis in the lily), or by the pith, or by the woody fibers? How do you know?

62. Stems as organs for support and leaf exposure. — When we studied the manufacture of carbohydrates by plants, we proved that green leaves must be exposed to sunlight in order to carry on this important function. When the leaves receive the proper amount of exposure, the food can be manufactured rapidly. Hence, we should expect to find that leaves are arranged in such a way as to secure the best amount of sunlight. Where plants are more or less crowded, as in forests or thickets, the main stems, such as the trunks of trees, usually grow tall, thus lifting the leaves to the light. The amount of light exposure of trees and of most other plants is largely increased by branches and their subdividing twigs, to which the leaves are attached.

In order that the trunk and its branches may be able to support the leaves and withstand the force of storms, thick-walled *wood-cells* are developed. Each wood-cell, when separated out from the rest, and examined with the high power of the compound microscope, is seen to be shaped somewhat like a tiny toothpick, and the thin ends of these cells fit together closely by overlapping. (See Fig. 15.)

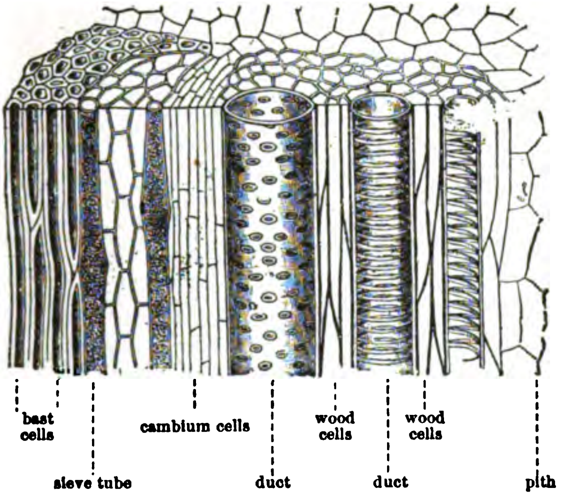

FIG. 15.—Woody bundle of sunflower stem.

Stems like the corn stalk and bamboo have most of their supporting material on the outside, and these stems are in the form of cylinders which are either hollow (as in grasses) or filled with pith through which pass the woody bundles (as in the corn stalk). It has been proved that when a given amount of material is arranged in the form of a hollow tube, it will withstand a much greater strain without breaking than when this material is in the form of a solid rod. This mechanical principle is made use of in the construction of the frame of a bicycle and of the pillars that support buildings.

63. Stems as organs for the transmission of sap. — Leaves not only require an abundance of sunlight, but they must also be supplied with water and other materials from the soil. Our experiment with red ink (see **61**) showed that the soil-water is carried upward through the woody portions of stems. A microscopical examination of thin sections of a stem (see Fig. 15) shows the presence of tubular cells known as *ducts*, similar to those found in the central cylinder of roots with which they are connected. These are the parts of the wood through which the soil-water passes most readily up to the leaves.

After the raw materials have been changed into the plant foods by green leaves, these plant foods, by the process of digestion, are changed into such a form that they can pass from the leaves into the fibrous bark in which are tubular cells known as *sieve-tubes*. (See Figs. 15 and 16.) Through these the liquid food passes down the stem to be stored away or used in the growth of root or stem. In young stems the pith rays or medullary rays (**59**, B, 3), the fine lines extending from the bark toward the center of the stem, are supposed to serve as channels for the passage of food across the stem and also for the storage of food.

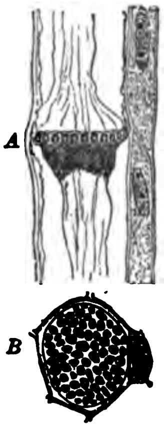

FIG. 16.— Sieve tube, that conveys sap downward through the leaf, stem, and root. *A*, longitudinal section showing edge view of sieve plate (in the middle); *B*, surface view of sieve plate.

In the type of stem represented in the corn, lilies, and palm trees, the woody material through which sap passes is not arranged in the form of annual rings, but the woody bundles are scattered through the pith. Each bundle consists of ducts that carry the soil-water up through the stem out into the leaves, of sieve-tubes that convey downward from the leaves the manufactured food substances, and of wood cells that help to strengthen the bundle.

64. Changes in stems during their growth. — In our discussion thus far, we have considered the adaptations of stems for exposing leaves to the light and for transmitting food materials to and from the leaves. But the stem has other important functions which we are now to consider. In a young twig, before the brown bark thickens and shuts out the light, the green bark, on account of the presence of chlorophyll, is enabled to carry on the manufacture of carbohydrates. In a very young stem the surface is covered by thin epidermis which helps to prevent the undue escape of moisture. In this layer are tiny openings that allow the inward and outward passage of gases that occur in breathing and food manufacture. Later this epidermis is replaced by the outer or brown bark, which serves as a means of protection against unfavorable weather conditions and insects. In this brown bark the tiny openings referred to above are developed into large openings known as *lenticels* which carry on the same functions. In an old tree the outer bark becomes very thick and corky and the green layer disappears entirely.

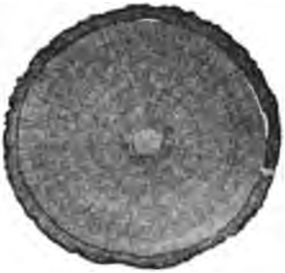
FIG. 17. — Cross section of a tree trunk showing bark, wood (with its annual rings and medullary rays), and pith at center. — (Courtesy of New York Botanical Garden.)

The growth of the tree in thickness, as already stated, is due to the activity of a layer of cells between the wood and the fibrous bark. This is the *cambium layer* (Fig. 15). In early spring the cambium cells by rapid growth and division form on their innermost surface a new layer of wood (which appears

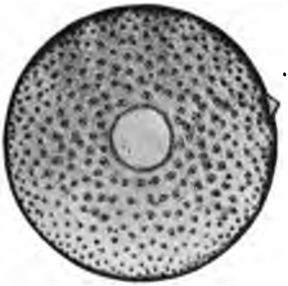

FIG. 18. — Cross section of young bamboo, showing hard outer rind, woody bundles, scattered through the pith. The center of the stem is hollow. — (Courtesy of New York Botanical Garden.)

as a ring in cross section), and on their outer surface more fibrous bark. As the season advances, the activity of these cells becomes less and less, and finally growth ceases during the winter.[1]

Stems of plants like the corn, bamboo, and palm have no true cambium layer, and therefore even in the case of plants of this type that live on from year to year no annual rings are formed. In the growth of these stems, new bundles develop in the pith between those already formed.

III. THE STRUCTURE AND ADAPTATIONS OF LEAVES

65. Leaf arrangement.[2] — Along the sides of twigs leaves are arranged in such a way as to secure as much light as possible without being shaded by the leaves above them. Thus in plants like the horse-chestnut, maple, and lilac, the leaves are arranged so that at a given level on the twig two leaves are opposite each other, while the next pair are at right angles to the first pair. This is known as an *opposite arrangement.* The beech, elm, and rose, on the other hand, have an *alternate arrangement,* only one leaf being found at a given level on the twig.

66. External structure of a horse-chestnut twig. — Laboratory Study No. 34. — (Optional.) (Maple, beech, or other woody twig may be used with slight verbal changes.)

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[1] Sometimes trees form more than one ring during a season.

[2] Before assigning this section for study, the teacher should demonstrate from leafy twigs (*e.g.* maple, horse-chestnut, lilac, elm, apple) the characteristic differences between the opposite and alternate arrangement of leaves.

A. *Leaf scars*. (The horseshoe-shaped scars with the raised dots like horseshoe nails indicate the places where the stalks of the leaves were attached.)

1. Do the leaf scars occur in pairs, or is there only one scar at a given level? How, therefore, were the leaves arranged on the stem?
2. Count the number of dots on several different leaf scars; these dots are the ends of the wood bundles that carried sap to the various leaflets. Look at the picture of horse-chestnut leaves. (See Fig. 20, K.) How many main veins do you find in one compound leaf? Compare this number with the number of dots on the leaf scars; what do you conclude?

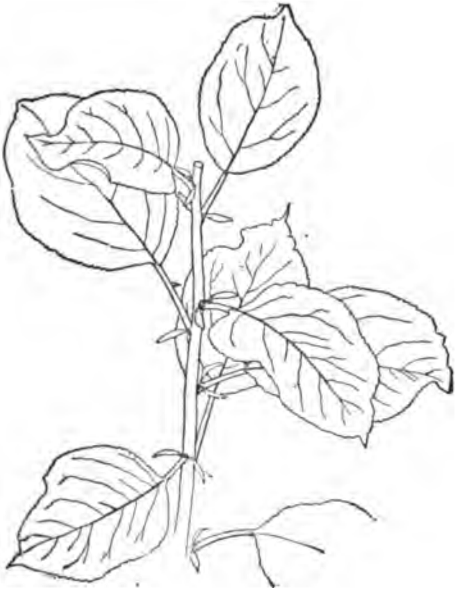

FIG. 19. — Spray of young apple tree, showing alternate arrangement. At the base of each leaf stalk is a pair of small stipules. — (Bailey.)

B. *Buds*. (At the end of most twigs is a single *terminal bud;* the buds along the side of the twig are *lateral buds*. Each bud is covered with *bud-scales*.)

1. State the position of each kind of bud on the twig. Where are the lateral buds found with reference to the leaf scars?

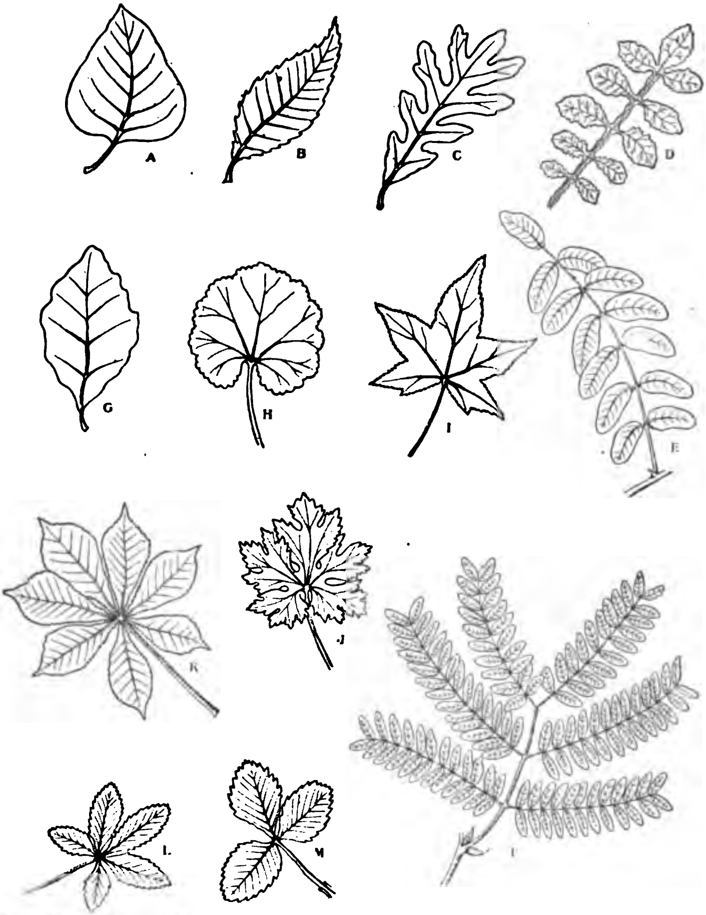

FIG. 20. — Forms of leaves. — (Courtesy of Furman and Miller, Botanical Aid, Western Publishing Co., Chicago, Ill.)

Simple leaves

A, lilac;
B, chestnut;
C, white oak;
D, celandine;
G, oak;
H, geranium;
I, sweet gum;
J, buttercup;

Compound leaves

E, locust;
K, horse-chestnut;
L, cinquefoil;
M, wild strawberry;
F, wild tamarind (twice compound).

2. Look carefully at the scales of the terminal bud to see if they have any definite arrangement. State whether or not this arrangement corresponds to that of the leaf scars.
3. (Demonstration.) Examine a terminal bud from which one or two scales have been removed. Bud-scales are modified leaves. How do these scales differ from ordinary leaves? What is the use of the scales to the bud? How are they adapted for this use?

C. *Bud-scale scars.* (These are also called *annual scars* because they are formed at the beginning of the growing season of each year when the terminal bud opens and its scales fall off. To prove this, remove one or two outside scales from a terminal bud, and note the scar thus formed.)

1. How many groups of bud-scale scars or annual scars do you find on the twig you are studying?
2. Since one set is formed each spring, how many years of growth are shown on the twig?

D. *Breathing pores* or *lenticels.* Look for small elevations on the bark. These locate the lenticels. Describe the lenticels.

E. Make a careful outline drawing of the twig, showing its form, the position and shape of the leaf scars with their woody bundles, the terminal and lateral buds, bud-scales, bud-scale scars, and lenticels. Label each of the structures shown in your drawing.

67. The structure of leaves. — Laboratory Study No. 35.

A. *Parts of a leaf.*

1. Examine a simple leaf, *e.g.* maple, geranium, or lilac, and note that it is made up of the following parts: a *leaf-stalk*, which attaches the main part of the leaf to the stem of the plant, and the *blade*, the flat, expanded portion.
   a. How does the blade differ in form from the leaf-stalk?
   b. Hold the leaf to the light. How many main veins do you find? Where are they smallest? By what are the larger veins connected?

c. Make a drawing, natural size, by tracing the outline of the leaf-stalk and blade. Draw carefully the principal veins and a few of their branches, being careful to show their relative size and their connections. Label leaf-stalk, blade, main veins, network of veins.

2. (Optional.) Examine a compound leaf, *e.g.* rose, clover, locust, pea, horse-chestnut. Notice that the blade is divided into three or more parts known as *leaflets*, which are attached either to the end of the leaf-stalk or on either side of the mid-vein of the compound leaf.

a. In what respect, therefore, does the blade of a compound leaf differ from the blade of a simple leaf?

b. Compare the arrangement of the leaflets in a leaf like the rose, locust, or pea with that in the Virginia creeper or horse-chestnut. Which leaves have the leaflets arranged like the bones in the palm of the hand (*palmately compound*), and which have the leaflets arranged along the side of the mid-vein as in a feather (*pinnately compound*, from Latin, *pinna* = feather)?

c. At the base of the leaf-stalk of the rose, clover, or pea leaf, notice two leaf-like objects (small in the case of the rose). These are known as *stipules*. Stipules are also found as a part of many simple leaves. How do stipules differ from the other parts of leaves? (See Fig. 19.)

B. Gross structure of leaves. — Secure thick leaves such as sedum, tulip, hyacinth, or onion.

1. Peel off from the upper and lower surface a thin membrane known as the *epidermis*. Hold the epidermis between yourself and the light. Tell what you have done and state two characteristics of epidermis.

2. Examine the material left after removing the epidermis, scraping it with a knife. This inner region of the leaf is known as *mesophyll* (Greek, *meso* = middle + *phullon* = leaf). Describe the mesophyll, stating how it differs from the epidermis.
3. Look carefully for veins in the mesophyll. Describe their appearance.
4. (Optional.) Make a diagram at least half an inch in thickness of a small portion of the cross section of the leaf you are studying, labeling upper epidermis, mesophyll, veins, and lower epidermis.

C. Microscopical structure of leaves. — Demonstration.

1. Strip off a piece of epidermis from one of the thick leaves named in *B* above; lay it on a glass slide, add a drop of water, and cover with a cover glass. Examine with the low power of the compound microscope, comparing the specimen with Fig. 21. Notice the shape of the cells of which the epidermis (shown by the faint outlines of their walls) is composed. Find little oval bodies scattered among the cells of the epidermis, each hav-

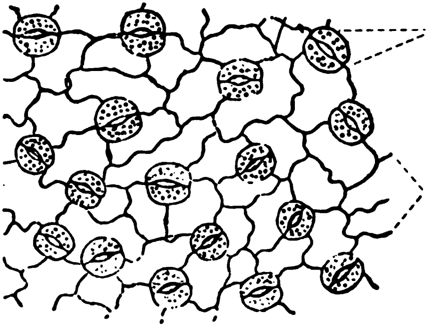

FIG. 21. — Lower epidermis of a leaf. — (Strasburger.)

ing an opening in the middle. This opening is called a *stoma*, plural *stomata* (Greek, *stoma* = mouth). Each stoma is surrounded by two *guard-cells*.

Make a diagram, greatly enlarged, of a stoma with its guard-cells, together with the cells of the epidermis that immediately surround it. Label cells of the epidermis, guard-cells, stoma.

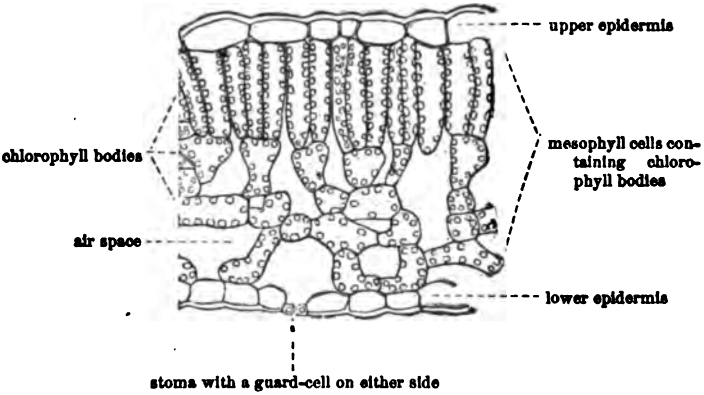
upper epidermis
chlorophyll bodies
mesophyll cells containing chlorophyll bodies
air space
lower epidermis
stoma with a guard-cell on either side

FIG. 22. — Cross section of a leaf. — (Strasburger.)

2. Study Fig. 22 and make out the shape and location of each of the following parts of which it is composed: upper epidermis, mesophyll cells, chlorophyll bodies, air spaces between the cells, lower epidermis, stoma. In your note-book make a drawing considerably enlarged showing a small portion of the cross section, and label each part.

68. Experiment to demonstrate the path of sap through leaves. — Laboratory Study No. 36.

Place in red ink the lower end of a leafy branch of any vigorous plant, *e.g.* geranium or bean seedling, and allow it to stand in sunlight or a warm place until the red color appears in the leaves.

1. Give an account of the experiment, stating your observations.
2. What do you conclude as to the part of the leaf through which soil-water is distributed to different parts of the blade?
3. What cells of the root did you find specially adapted for absorbing water from the soil? Through what regions of the root and stem is sap carried up to the leaves?

69. Is water vapor given off by the leaves of a green plant? — Laboratory Study No. 37. Demonstration.

1. Wrap sheet rubber or thin oilcloth about a pot containing a vigorous plant which has been thoroughly watered. Tie the rubber or oilcloth tightly about the stem to prevent the escape of water from the soil. If rubber tissue cannot be obtained, melted paraffin may be poured over the soil, and the pot painted with hot paraffin. Cover the plant thus prepared with a large bell jar with the inner surface dry, and stand it in the sun for a few hours.
   - *a.* Describe the preparation of the experiment, stating the reason for using the rubber or paraffin.
   - *b.* State your observations and conclusion.
   - *c.* Why is the bell jar necessary?
   - *d.* What becomes of the water vapor given off by the leaves of trees?

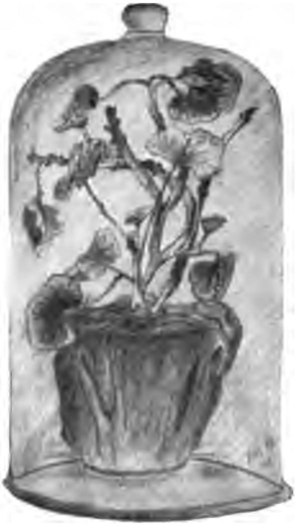

FIG. 23. — Apparatus to show the excretion of water from a plant.

2. (Optional.) Put the plant prepared as above on one of the scale pans of a balance and with it a stoppered graduate or a stoppered bottle. On the other pan put weights enough to equalize the balance. At the end of 24 hours put enough water into the graduate or bottle to cause the weights on the two pans to be equal.
   a. Describe the preparation of the experiment.
   b. What volume of water was necessary to equalize the weights (*i.e.* how much water was given off from the plant in 24 hours)?
   c. In a similar way add water each 24 hours for a week or until the plant shows signs of wilting. What is the total amount of water given off during the experiment?
   d. Bearing in mind the relative amount of leaf surface of this plant and on the trees of a forest of even a few acres, what would you infer as to the quantity of water given off by the trees of a forest during a summer season?

70. Leaves as organs for food manufacture. — While studying the manufacture by plants of carbohydrates (sugar and starch) we showed that the raw materials necessary for this process are water and carbon dioxid. We have proved that water enters the root-hairs by osmosis and travels in a system of ducts through the woody portion of roots and stems out to the leaves. Here the ducts of the stems connect with a network of veins containing similar ducts by means of which the soil-water is supplied to the cells that are to manufacture the food. The carbon dioxid that is needed is secured from the air. This gas passes through the openings (stomata) in the epidermis, and enters the air spaces in the mesophyll, and finally reaches the cells containing the chlorophyll bodies.

The sunlight acting upon the chlorophyll bodies enables them to combine the elements found in the water and carbon dioxid to form carbohydrates. These, as we have seen, are probably used in the manufacture of proteins. In the leaves, as elsewhere in the plant, the various foods are digested and thus are prepared to be carried by the tubular cells (sieve tubes) in the veins and down through similar tubular cells in the fibrous bark. (Fig. 16.)

71. Excretion of the by-products of food manufacture. — We showed in **35** that during the process of carbohydrate manufacture oxygen is set free, and this gas is given off through the stomata into the air. Water, too, is a by-product of food manufacture and assimilation. In the manufacture of proteins mineral matters are necessary, and these are carried up the stem dissolved in the soil-water. Since, however, the soil-water is such a dilute solution, great quantities of this liquid must be supplied; hence, much more water is taken in than is needed for food manufacture or making of protoplasm. This excess of water is given off in large quantity by the leaves of green plants (see **69**).

The amount of water thus excreted by leaves is regulated more or less by the action of the guard-cells that surround each stoma. When the plant is well supplied with water, the stoma remains wide open. If, on the other hand, the leaves lack a sufficiency of water, these guard-cells close in upon the stoma, and so prevent undue loss of moisture. In plants having leaves in a horizontal position, the stomata are mostly located on the lower surface, the upper surface, which is more exposed to the sunlight, being covered with a continuous layer of epidermal cells. Were the epidermis altogether absent from leaves, the mesophyll cells would soon lose so much water that they would die.

72. Storage of foods in plants. — The foods that are manufactured in the chlorophyll-bearing cells may be carried, as we have seen, to other parts of the plant, there to be stored until needed. Whenever large amounts of starch, sugar, protein, or fat are thus stored, the organs containing these substances frequently become enlarged (*e.g.* carrot (Fig. 81), potato (Figs. 49, 60), and onion) and the walls of the cells in these organs usually remain thin and soft, permitting the inward and outward passage of food. (See Fig. 9.)

73. Summary of functions of the parts of the nutritive organs of green plants.

NAME OF PART	WHERE PART IS FOUND	PRINCIPAL FUNCTION OR FUNCTIONS OF PARTS
Epidermis	Covering of root	Absorbs soil-water, largely through root-hairs
Epidermis	Covering of stem and leaves	Protects inner layers, prevents undue escape of moisture
Lenticels	Brown bark of stem	Permit entrance of O and CO_2 and escape of O and CO_2
Stomata	Epidermis of leaves	Permit entrance of O and CO_2 and escape of O and CO_2
Guard-cells	Surround stomata	Regulate escape of H_2O
Air spaces	Between mesophyll cells	Serve as reservoirs of O and CO_2 and water vapor
Chlorophyll-bearing cells	Mesophyll of leaves, green bark of stem	Manufacture carbohydrates
Ducts	Central cylinder of root, woody part of stem, veins of leaves	Transport soil-water upward through the plant
Sieve tubes	Fibrous bark of stem, veins of leaves	Transport digested foods downward through plants

NAME OF PART	WHERE PART IS FOUND	PRINCIPAL FUNCTION OR FUNCTIONS OF PARTS
Wood cells	Central cylinder of root, woody part of stem, veins of leaves	Resist forces tending to break roots, stems, or leaves
Cambium layer	Between bark and wood of stem	Provides for growth of wood and fibrous bark or bast
Pith	Interior of stem	Stores food
Pith-rays	Woody layer of stem	Transfer food across stem, and store food

CHAPTER VI

RESPIRATION AND THE LIBERATION OF ENERGY IN PLANTS

I. THE STORAGE AND LIBERATION OF ENERGY

74. Examples of energy in plants. — By *energy* we mean the capacity to do work. In the preceding chapters we have considered to some extent the structure of various parts of plants and some of the functions which they are fitted to perform. Now to carry on most of these functions requires the expenditure of energy on the part of the plant. Thus, for example, roots in growing expend considerable energy, pushing their way through the soil. Stems in like manner exert energy in lifting to the light and air their weight of branches and leaves. We know, too, that soil-water is carried up through plants to considerable heights (several hundred feet in very large trees), that substances obtained from the soil and air are transported from one part of a plant to another. Still another form of energy exhibited to a certain degree by plants is heat, as the following experiment will show.

75. To prove that heat energy is liberated in growing seedlings. — Laboratory Study No. 38.

Secure two wide-mouthed bottles of the same size (lightning fruit jars will answer) and put some wet blotting paper in the bottom of each. Fill one of the jars half full of sprouting peas. Fill the other jar half full of peas that have been killed by being soaked in a 5 per cent solution of formalin for twenty-four hours. Rinse the seeds with boiled water to remove the preserving fluid. Get two thermometers that have approximately the same temperature reading in the air of the laboratory.[1] Push the lower end of the thermometer down among the sprouting seeds so that the mercury will be covered by the seeds. Do the same with the second thermometer in the jar of dead seeds. Set the jars side by side in a warm place for twenty-four hours or more.

1. Describe the preparation of this experiment. In what respects are the conditions the same in both jars? In what one respect do the two jars differ?
2. Take the temperature readings of the thermometer in each of the two jars and record results. What difference do you notice in the temperature of the seeds in the two jars?
3. What is your conclusion from the experiment as to the liberation of heat energy in seedlings?

76. Energy and its transformations. — We see from the preceding discussion and experiment that plants exhibit considerable energy or ability to do work. Animals and man, however, show far more striking proofs of the output of energy in their muscular movements, for example, in running, swimming, and flying. Various machines, also, enable us to make use of different forms of energy, and, as we shall now see, one kind of energy may be readily transformed into another by means of these machines. Suppose we consider the work that goes on in an electric power plant. The coal that is shoveled into the fire-box beneath the boilers by the process of oxidation liberates heat, which is one of the forms of energy. The heat changes the water into steam, which expands and so exerts its power to run the engine, and thus heat energy is transformed into the energy of motion. When the engine is connected with a dynamo, this energy of motion is changed into electrical energy, and this in turn may be converted into light or heat energy in our houses or into energy of motion, as, for instance, in the running of a trolley car.

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[1] If a difference in the reading of the two thermometers is evident, this difference should be computed in the later readings on the thermometers.

77. Source of the energy liberated in living things. — In all these marvelous transformations of energy that we have just enumerated no new energy is created and none is destroyed. Whence, then, comes this abundant supply of energy? We shall find the probable answer to this question in considering again the processes carried on in the leaves of plants. From the sun comes the radiant energy that is absolutely essential for the activity of the chlorophyll bodies, by which carbohydrates are formed. In the formation of these compounds, the sun's radiant energy is used and apparently disappears.[1] In reality, however, it has only been stored in the chemical compounds formed thereby, since, as we have said above, energy cannot be destroyed.

78. Oxidation as a means of liberating energy. — Let us now refer once more to the processes that take place in an electric power plant. We have just said that the energy derived from the rays of the sun is stored up in the wood, coal, and other fuel. In order to set free from these compounds the energy they contain, the wood or coal must be burned, or in other words combined with oxygen. Every one knows that when we wish to secure a large amount of heat from our fuel we open wide the drafts in order to secure a plentiful supply of oxygen. We demonstrated in our studies in oxidation that whenever a substance is burned, heat energy is liberated and usually light is seen. The energy set free by the oxidation of fuel may be transformed at one time into light, at another time into motion, or again into heat.

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[1] The authors are indebted to Mr. Paul B. Mann of the Morris High School Department of Biology for the following demonstration of the effectiveness of the radiant energy of the sun. Place a radiometer (usually found in the physics equipment of schools) in direct sunlight, and then remove it from the sun's rays. Try also the effect of an electric light by bringing the radiometer near the light bulb, and then slowly removing it to a distance.

It is probably true that the liberation of energy in living plants is somehow due to the action of oxygen. The process, however, is doubtless extremely complicated, and just what takes place no one knows. Certainly oxygen in some form is essential for the life of every plant and animal. That this is true of plants, the following experiment will show.

79. To prove that seeds need air in order to grow. — Laboratory Study No. 39. Demonstration or Home Work.

Secure two wide-mouthed bottles and place in the bottom of each a wet sponge or some wet blotting paper, and pour enough water in each bottle just to cover the sponge or paper. Fill both bottles with pea seeds that have been soaked in water for twenty-four hours. Insert a tightly fitting cork into the mouth of one of the bottles to exclude the air. Leave the other bottle open to the air, and add enough water from day to day to make up for the loss by evaporation. Put both bottles in a warm place.

1. Describe this experiment, showing in what respects the conditions are the same for both groups of seeds.
2. In what one respect do the two groups of seeds differ?
3. At the end of several days examine both bottles of seeds, and state your observation concerning the amount of growth in each bottle.
4. State clearly your conclusion as to the necessity of air for growth of pea seedlings.

80. Relation of oxygen and carbon dioxid to oxidation. — We have now demonstrated that seedlings will not grow without air. Biologists have proved conclusively that oxygen is the element in the air that is essential for the work of all plants, and that without it they die. Hence, we may conclude, as in the case of the furnace, that the necessary energy of a plant is in some way set free by oxygen acting upon plant compounds. When oxidation of compounds containing carbon takes place, we find that carbon dioxid is produced (11). Now if processes like oxidation are carried on in plants, we should expect to find that CO_2 is formed. The following experiment proves clearly that such is the case.

81. To prove that carbon dioxid is formed during the growth of young seedlings. — Laboratory Study No. 40.

In the bottom of two large jars (fruit jars will answer) place some wet blotting paper. Fill one of the jars half full of germinating peas, and place a small wide-mouthed bottle full of lime water on top of the seeds. Screw the top of the jar on tightly. In the other jar place a bottle of lime water and cover as in the previous jar. At the end of twenty-four hours or more examine the lime water in both jars.

1. Describe the preparation of the experiment.
2. Compare the condition of the lime water in both jars. What has caused the change in the lime water in both jars?
3. Air, as we proved, contains a little carbon dioxid. Bearing this fact in mind, account for the difference in the appearance of the lime water in the two jars.
4. What gas, therefore, do you find to be given off during the growth of young seedlings?

II. RESPIRATION

82. Respiration in plants. — It should be clear from our study thus far that all plants require oxygen, and that this oxygen brings about in plants a process resembling oxidation at least in the releasing of heat and other forms of energy and in the producing of carbon dioxid. These various processes take place in each living plant cell. Hence, every cell uses oxygen and must necessarily form carbon dioxid. This process which goes on in every living cell is *respiration.*

In green plants during the night, when carbon dioxid is not being used for starch manufacture, this gas is given off to the surrounding air, which probably is not true to any great extent during the daytime. The taking in of oxygen and the giving off of carbon dioxid by plants corresponds to breathing in animals. Breathing is carried on in plants through the thin walls of roots, through the lenticels of stems, and through the stomata of leaves. The principal distinction, therefore, between breathing and *respiration includes the taking in of oxygen, the use of oxygen by the cells* (*in oxidation*), *and the giving out of carbon dioxid.* The process of breathing must not be confused with that of carbohydrate manufacture, and the following outline will show the fundamental difference between the two.

	CARBOHYDRATE MANUFACTURE	RESPIRATION (INCLUDING OXIDATION)
Where carried on	In cells containing chlorophyll	In all living cells
When carried on	In sunlight	Throughout life of cell
Substances taken from air	CO_2	O
Substance formed in plant	Carbohydrates	CO_2
Waste substance excreted to air	O	CO_2
Advantage to plant	Manufacture of food	Release of energy

CHAPTER VII

REPRODUCTION IN PLANTS

I. THE STRUCTURE AND FUNCTIONS OF FLOWERS

83. Necessity of plant reproduction. — Every one knows that plants like peas, beans, and corn live but one year. Shrubs and trees, while they often live for many years, finally die. This is true of all plants. It is evident, therefore, that unless there were some means of producing new plants to take the place of those now living, all forms of plant life would soon cease to exist. The process by which new plants are formed is known as *reproduction*. In the higher plants this process is carried on by *flowers*, the function of which is to produce *seeds* which will develop into *new plants*. We are now to study the various parts of flowers and to consider the work of each part in this process of reproduction.

84. Study of tulip flower (spring study). — Laboratory Study No. 41.

Material: While the trillium is a more satisfactory flower for beginning the study of the process of reproduction, the danger that the wild flowers will become exterminated seems to make the study of the tulip advisable, especially in large city high schools. The two flowers, however, are usually in season at the same time, and if possible at least a few of the trilliums should be secured for demonstration. If this is impossible, the distinction between calyx and corolla should be taught from the apple blossom or other common flower.

A. *Floral envelopes.* — Most flowers have parts shaped more or less like leaves which have either green or bright colors. These parts are arranged in one or more circles and make up the *floral envelopes*.

1. How many parts are there in the floral envelopes of a tulip? State the color or colors of these parts in the flower you are studying.
2. When there are two circles to the floral envelopes, an outer composed of green parts and an inner made up of brightly colored parts (as in the trillium or the apple blossom), distinct names are given to the various parts. The outer circle is called the *calyx* and its parts are known as *sepals;* the inner circle is called the *corolla* and each of its parts is called a *petal.*
   a. State the number and color of the sepals in the calyx of the trillium.
   b. How many petals do you find in the corolla? Describe their color.
3. Draw a side view of a tulip before it has fully opened. Label flower-stalk and floral envelopes.

B. *Essential organs.* — In the central part of the flower are the organs without which the work of the flower cannot be performed. For this reason they are called the *essential organs.*

1. The organs arranged in a circle just within the floral envelopes are known as *stamens.* State the situation and the number of stamens in the tulip. What is the number of stamens in the trillium or apple blossom?
2. Each stamen consists of a stalk called the *filament* and an enlarged part known as the *anther.* Name and describe each of the parts of a stamen.
3. Make a drawing twice its natural size of one of the stamens. Label filament, anther.
4. Find a flower the stamens of which have a powdery substance known as *pollen.* Which part of the stamen produces the pollen?
5. The organ at the center of the flower is called the *pistil.* It consists of three divisions at the top

which together are known as the *stigma*, and the remainder of the pistil known as the *ovary*. Describe the pistil of the tulip (and of the trillium) as to position, shape, and color of its parts.

6. Make a drawing twice its natural size of the pistil. Label stigma, ovary.
7. Cut thin cross sections of a well-developed ovary, lay them on a dark-colored background, and study one or more of them with a magnifier to make out the following parts: *wall of the ovary*, small objects within the ovary known as *ovules*. (These ovules develop into *seeds*.) Describe what you have done and tell what you have seen.
8. Make a drawing at least an inch in diameter of a cross section of the ovary, labeling ovary wall and ovules.
9. (Optional.) Make a drawing (corresponding in size to that called for in 6 above) of a lengthwise section of the ovary to show wall of ovary, ovules. Label.

85. Study of the gladiolus flower (autumn study). Laboratory Study No. 42.

Note to the teacher. — Be careful to remove each flower close to the central stalk, so that the ovary may not be injured.

A. Parts of the flower.

1. Remove the two leaves at the base of the flower, since these leaf-like organs do not belong to the flower. The outer brightly colored parts of the flower are called the *floral envelopes*. These colored parts unite to form a greenish tube below.
   - *a.* Count and record the number of divisions of which the floral envelopes are composed.
   - *b.* State whether or not these divisions are all of the same size.
2. The slender stalks with purple tips, inside the floral envelopes, are called *stamens*. How many stamens do you find?

3. The single white stalk with three divisions at the top is the upper part of the *pistil.* The dark green body below the tubular part of the floral envelopes is the lower part of the pistil.

   Is the top of the pistil in the flower you are studying lower or higher than the stamens?
4. Make a drawing, natural size, of the side view of the flower, and label the following parts: the divided portion of the floral envelopes, the tubular portion of the floral envelopes, the stamens, the pistil.

B. Essential organs. — The stamens and pistils are called the essential organs of flowers because without them the work of the flower cannot be performed.

1. Carefully slit open the tubular part of the floral envelopes down to the lower part of the pistil. Then remove the floral envelopes, leaving the entire pistil uninjured.
   - *a.* State what you have done.
   - *b.* To what are the stamens attached?
   - *c.* The enlarged part at the top of the stamen is called the *anther,* the stalk-like part is called the *filament.* Name and describe the parts of a stamen.
2. Make a drawing, natural size, of a portion of the floral envelope to which a stamen is attached. Label division of floral envelopes, anther, filament.
3. Find a flower the stamens of which have a powdery substance known as *pollen.* Which part of the stamen produces the pollen?
4. The pistil consists of an enlarged portion at the base called the *ovary,* a stalk-like portion called the *style,* and a spreading portion at the top, each part of which is called a *stigma.* Name and describe each part of the pistil.
5. Make a drawing, natural size, of the pistil and label ovary, style, stigmas.
6. Cut thin cross sections of a well-developed ovary, lay them on a dark-colored background, and study one or more of them with a magnifier to make

out the following parts: *wall of ovary*, small objects within the ovary known as *ovules*. These ovules develop into *seeds*. Describe what you have done and tell what you have seen.

7. Make a drawing at least an inch in diameter of a cross section of the ovary, labeling ovary wall, ovules.

8. (Optional.) Make a drawing (corresponding in size to that called for in 7 above) of a lengthwise section of the ovary to show wall of ovary, ovules. Label.

86. Pollination. — We have learned in our study of flowers that pollen is produced in the anther of the stamen, and ovules in the ovary of the pistil. Before an ovule can develop into a seed, however, certain portions of a pollen grain and of an ovule must be combined. Pollen must, therefore, be transferred from the anthers to the pistils, and to this process is given the name *pollination*. We shall now learn by experiment some adaptations of the pistil for receiving and holding the pollen.

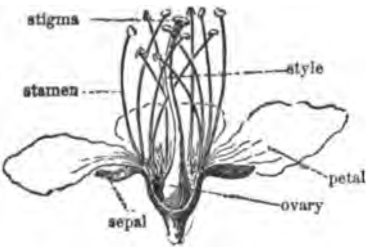

Fig. 24.—Structure of a plum blossom. (Bailey.)

87. Experiment to show pollination. — Laboratory Study No. 43.

Rub a small brush or the end of a toothpick over a stamen (*e.g.* tulip, Easter lily, or gladiolus) which has an abundance of pollen, and then brush this pollen over the surface of the stigma.

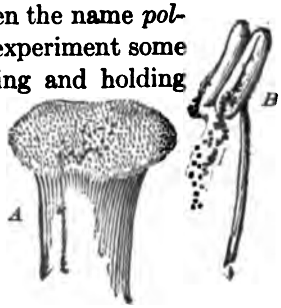

Fig. 25. — *A*, pollen adhering to stigma; *B*, pollen of plum escaping from the anther of a stamen. — (Bailey.)

1. Describe what you have done.
2. Examine the surface of the stigma with a magnifier and state what causes the pollen to stick to the stigma.

88. Microscopical Demonstration of Pollen Grains and their Development. — Laboratory Study No. 44. (Optional.) Prepare some sugar solution by adding to ten teaspoonfuls of water one teaspoonful of molasses or grape sugar and heat to boiling point. Put some of this sugar solution in a clean Syracuse watch glass. When the solution has cooled, mix with it some pollen from the flower of a tulip, a trillium, a sweet pea, or nasturtium. Several of these glasses might well be prepared with slightly different strengths of sugar solution and piled one above the other to keep out mold spores. Leave the glasses until the pollen grains have germinated. Study the preparation with the low power of the compound microscope.

1. Find some pollen grains that have not begun to grow tubes. Describe the form of one of the pollen grains.

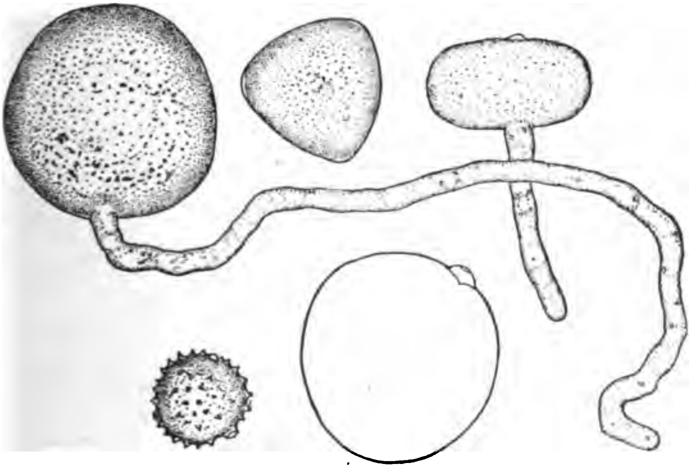

Fig. 26. — Different kinds of pollen grains, highly magnified, two of them forming pollen tubes. — (Duggar.)

2. Find several grains that have formed tubes. What is the color and shape of the tubes?
3. Make a drawing at least a half inch in diameter of a pollen grain before it has sprouted and a drawing of another grain that has sprouted. Label pollen grain, pollen tube.

89. Pollination, germination of pollen grains, and fertilization. — We have now learned that pollen by the process of pollination is carried to the stigma of the pistil and adheres to the stigma by a sticky substance which is easily seen on the stigma of the Easter lily and often by hairs, also, as is the case in the tulip and gladiolus. It has been proved that this sticky substance contains sugar which together with other materials furnishes food for the growth of pollen tubes (see 88). As each tube forms, it makes its way down through the stigma and style (if present), and finally reaches an ovule in the ovary. The tip of the tube now penetrates an opening called the *micropyle* (Greek, *micro* = small + *pula* = gateway) in the ovule. Part of the living substance of the pollen grain now unites with a part of the living substance of the ovule. This union is known as *fertilization.* After fertilization has taken place the ovule develops into a seed.

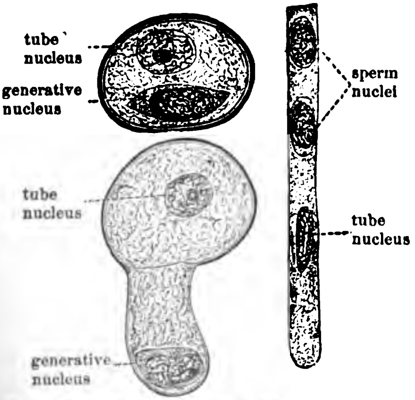

FIG. 27. — Pollen grain of lily and the development of the pollen tube, highly magnified. — (After Strasburger.)

90. The cellular nature of pollen and ovules. — (If flowers are studied in the autumn, it is suggested that this Section be omitted until after the cellular structure of plants has been considered.) When the pollen grains are first formed in the anther, each consists of a single cell. Later the nucleus of this cell divides and forms two nuclei, one of which is the *generative nucleus*. The generative nucleus then divides and forms two *sperm nuclei*. The ovule is more complex in its structure, being composed of many cells of different kinds. But here, as is the case with the pollen grain, there is one important cell that is essential in the process of reproduction, and this is known as the *egg-cell* (Figs. 27 and 29, A).

91. The formation of an embryo. — When the pollen grain germinates and forms the tube, the sperm nucleus is carried by the tube down through the stigma and style into the cavity of the ovary, and finally through the micropyle of the ovule, until one of the sperm nuclei comes to lie beside the nucleus of the egg-cell. The two nuclei now unite in the process of fertilization to form a *fertilized egg-cell*. The nucleus of this cell then divides and later the cell-body, thus forming two distinct cells. Each of these divides to form two cells, and the four cells thus produced give rise to eight, then sixteen, thirty-two, and so on, until a many-celled structure is developed which is a miniature plant called the *embryo*. This embryo, together with other parts of the ovule, constitutes the *seed*. Some of the cells of the embryo will later form the roots, others the stem, and still others the leaves of the plant (Fig. 29, A-E).

Hence, the new plant formed by this method of reproduction is clearly descended from two different parents, one parent flower furnishing in its pistil the egg-cell and the other in its stamen the fertilizing pollen. We may, therefore, give the following as a general definition of the process we are studying: *Fertilization is the union of the nucleus of*

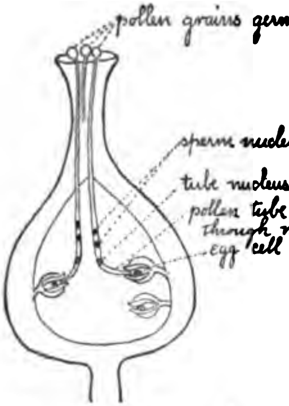
pollen grains germinating
sperm nuclei
tube nucleus
pollen tube entering through micropyle
egg cell

FIG. 28. — Diagram of a longitudinal section of a pistil showing germination of pollen grains.

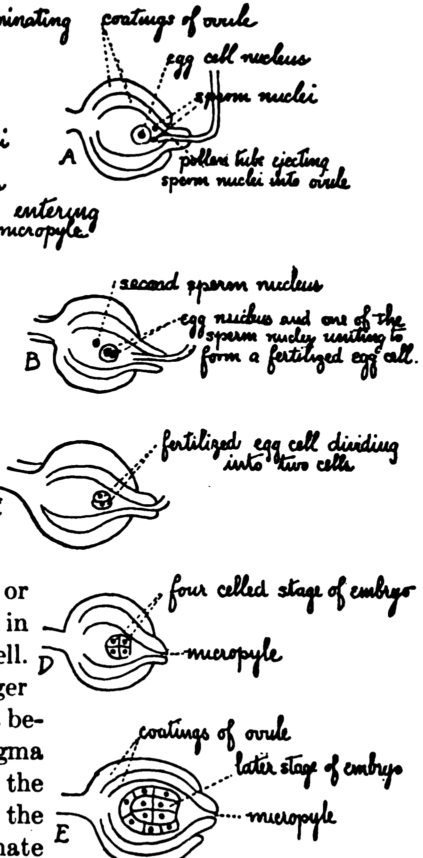
coatings of ovule
egg cell nucleus
sperm nuclei
A
pollen tube ejecting sperm nuclei into ovule
second sperm nucleus
egg nucleus and one of the sperm nuclei uniting to form a fertilized egg cell.
B
fertilized egg cell dividing into two cells
C
four celled stage of embryo
micropyle
D
coatings of ovule
later stage of embryo
micropyle
E

FIG. 29. — Fertilization of an ovule and the early stages in the development of an embryo. — (Diagrammatic.)

a sperm cell with the nucleus of an egg-cell. Only one pollen grain or sperm cell can be used in fertilizing each egg-cell. Usually, however, far larger numbers of pollen grains become attached to the stigma than can be used by the ovules in the ovary. All the pollen grains that germinate produce pollen tubes which may be said to begin a race down the stigma and style. The tubes that first enter ovules are the ones that carry on the process of fertilization. Those that are beaten in the race are of no further use and therefore die.

92. Self-pollination and cross-pollination. — *Pollination,* we have said, is the transfer of pollen from the anther to the stigma. When the pollen is carried from the anther of a flower to the stigma of the pistil of the same flower, the process is known as *self-pollination.* In many of the flowers that are self-pollinated, the anthers are above the stigmas, and when the pollen is ripe, the anthers burst open and allow the pollen grains to fall upon the stigma or stigmas.

If pollen is carried from the anther of a flower to the stigma of the pistil of a flower of the same kind but on another plant, this transfer is called *cross-pollination.* Cross-pollination is often accomplished by the help of the wind, as in the flowers of the corn, of grasses, and of many trees. In these cases the pollen is dry and light, and the pistils are usually hairy or feathery to catch and hold the pollen grains.

Most bright-colored and sweet-scented flowers (like the pansy and the clover) are visited by bees or other hairy insects which carry pollen on their mouth parts, bodies, and legs from one flower to another, thus insuring cross-pollination. We shall now study the pansy as a type of insect pollinated flowers.

93. Adaptations of the pansy for cross pollination. — Laboratory Study No. 45.

A. *Floral envelopes.* — When there are two circles to the floral envelopes, an outer composed of green parts and an inner made up of brightly colored parts as in the pansy, distinct names are given to the various parts. The outer circle is called the *calyx,* and its parts are known as *sepals;* the inner circle is called the *corolla,* and each of its parts is called a *petal.*

1. State the number and color of the sepals.
2. How many petals are there? Describe the color or colors of each.

3. Locate the pairs of petals that are nearly alike in size and shape.
   State the position of the odd petal.
4. On which of these petals do you find the most striking spots or lines of color?
5. Make a drawing of the pansy in its natural position, front view, and natural size. Label top petals, side petals, lower petal, hairs on side petals, color spots.
6. Remove the two upper petals, and the two side petals. Now observe the tapering projection on the lower or odd petal extending upward and backward between the sepals. This is called the *spur*.
   - *a.* Tell what you have done and seen.
   - *b.* Carefully remove the lower petal with the spur attached, and make a drawing of it, natural size. Label the spur and color spot.
7. Slit open the spur. Is the spur hollow or solid?
8. The spur contains a sweet liquid called *nectar* which attracts the bees and other insects. If you find any nectar, describe it and tell how you found it. Describe the taste of the nectar.
9. In what two ways, therefore, may pansies attract bees?
10. On which petal would a bee be most likely to alight in visiting a pansy? What is there on this petal to guide the bee toward the supply of nectar?
11. (Optional.) What structures on the side petals might make it difficult for the bee to insert its mouth parts in this region?

B. Stamens.

1. Observe the stamens arranged around the pistil. Carefully separate them with a needle or pin. State the number and situation of the stamens.
2. Carefully bend two or more stamens away from the pistil, and with the help of a magnifier look

on their inner surface. Tell what you have done, and state whether the openings in the yellow anthers from which the pollen is discharged are found on the inner surface (next the pistil) or on the outer surface of the anther.

C. Pistil.

1. Examine the pistil after the stamens have been removed. Carefully describe the three parts (ovary, style, and stigma) of which it is composed.
2. Observe a tiny cavity on the tip of the stigma. The inside of this cavity is the real stigma or stigmatic surface. Describe the shape and state the situation of the stigmatic surface.

D. Cross-pollination of the pansy by bumblebees.

1. Hold a pansy in its natural position.
   - *a.* State the situation of the stamens with reference to the odd petal (*i.e.* are they above or below this petal?).
   - *b.* On what, therefore, will pollen probably fall if it is shaken out of the anthers?
2. To determine whether or not what you have just stated is true, thrust a slender tooth-pick under the stigma and then under the stamens and into the spur. Shake the flower gently and then withdraw the tooth-pick and examine the surface with a hand magnifier. Tell what you have done and state whether or not pollen is found on the tooth-pick.
3. Examine a bumblebee. On what part of the insect (*i.e.* mouth-parts, head, or body) would the pollen be most likely to fall when the bee

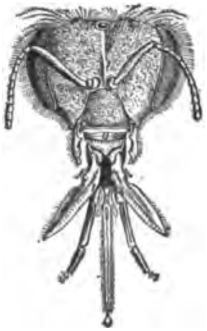

FIG. 30. — Head of a bee.

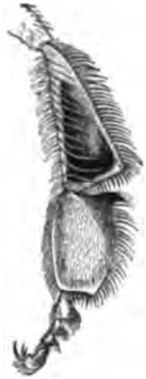

FIG. 31.—Hind leg of a worker bee.

thrusts its mouth-parts into the spur as you have just done with the tooth-pick? How are all these parts adapted to hold pollen? (Compare with Figs. 30, 31.)

4. Still holding the pansy in its natural position, notice and state the position of the stigma with reference to the odd petal.
5. Now push a tooth-pick which has pollen on it, a second time into the spur. State whether or not the tooth-pick hits the stigmatic cup before you get it under the stigma.
6. Why, therefore, will a bee that has just been to one pansy flower be almost certain to deposit pollen on the stigmatic cup of the next pansy it visits?
7. (*Optional* home work.) Write a paragraph on "The Visit of a Bee to a Pansy Blossom," giving a complete account of what the bee does and how it does it.

94. **The advantages of cross-pollination in the pansy.** — Charles Darwin, the great English biologist, proved by a long series of experiments that seeds produced as the result of cross-pollination develop into far more healthy plants than do the seeds which are formed after self-pollination. Among the plants with which he experimented was the pansy (*Viola tricolor*). He planted in each of five pots seeds that had been produced by cross-pollination, and an equal number of seeds that were the result of self-pollination. The results of the experiments are given in his own words as follows: "The average height of the fourteen crossed plants is here 5.58 inches, and that of the fourteen self-fertilized 2.37; or as 100 to 42. In four of the five pots, a crossed plant flowered before any one of the self-fertilized; as likewise occurred with the pair raised during the previous year. These plants without being disturbed were now

turned out of their pots and planted in the open ground, so as to form five separate clumps. Early in the following summer (1869) they flowered profusely, and being visited by humble-bees set many capsules which were carefully collected from all the plants on both sides. The crossed plants produced 167 capsules, and the self-fertilized only 17; or as 100 to 10. So that the crossed plants were more than twice the height of the self-fertilized, generally flowered first, and produced ten times as many naturally fertilized capsules.

"By the early part of the summer of 1870 the crossed plants in all the five clumps had grown and spread so much more than the self-fertilized, that any comparison between them was superfluous. The crossed plants were covered with a sheet of bloom, whilst only a single self-fertilized plant, which was much finer than any of its brethren, flowered. The crossed and self-fertilized plants had now grown all matted together on the respective sides of the superficial partitions still separating them; and in the clump which included the finest self-fertilized plant, I estimated that the surface covered by the crossed plants was about nine times as large as that covered by the self-fertilized plants. . . .

"The ensuing winter was very severe, and in the following spring (1871) the plants were again examined. All the self-fertilized were now dead, with the exception of a single branch on one plant, which bore on its summit a minute rosette of leaves about as large as a pea. On the other hand, all the crossed plants without exception were growing vigorously. So that the self-fertilized plants, besides their inferiority in other respects, were more tender.

"Another experiment was now tried for the sake of ascertaining how far the superiority of the crossed plants, or to speak more correctly, the inferiority of the self-fertilized plants, would be transmitted to their offspring. The one crossed and one self-fertilized plant, which were first raised, had been turned out of their pot and planted in the open ground. Both produced an abundance of very fine capsules, from which fact we may safely conclude that they had been cross-fertilized by insects. Seeds from both, after germinating on sand, were planted in pairs on the opposite sides of three pots.

The naturally crossed seedlings derived from the crossed plants flowered in all three pots before the naturally crossed seedlings derived from the self-fertilized plants.

"The average height of the six tallest plants derived from the crossed plants is 12.56 inches; and that of the six tallest plants derived from the self-fertilized plants is 10.31 inches; or as 100 to 82. We here see a considerable difference in height between the two sets, though very far from equalling that in the previous trials between the offspring from crossed and self-fertilized flowers. This difference must be attributed to the latter set of plants having inherited a weak constitution from their parents, the offspring of self-fertilized flowers; notwithstanding that the parents themselves had been freely intercrossed with other plants by the aid of insects." ("Cross and Self Fertilization in the Vegetable Kingdom.")

Darwin, therefore, proved conclusively by these careful experiments (1) that pansy blossoms which were cross-pollinated produced ten times as many seeds as those that were self-pollinated; (2) that the plants developed from these seeds, produced as a result of cross-pollination, were far more vigorous and prolific; and (3) that the descendants of the plants produced by self-pollination, even when their flowers were cross-pollinated, were not able to develop seeds capable of as vigorous growth as the descendants of plants produced continuously by cross-pollination.

95. Prevention of self-pollination. — We have found that the pansy is well adapted to bring about cross-pollination, and since, as Darwin proved, cross-pollination results in seeds being formed which produce much more vigorous and fruitful plants, we should expect that the pansy would have developed some means of preventing self-pollination; and this, as we shall see, proves to be the case.

The anthers of the pansy, as we saw, are joined about the pistil so as to form a band, and the openings for the escape of pollen are on their inner surfaces, next to the style and ovary. When the pollen is shaken out of the anthers, it first collects in the space between the anthers and the pistil. In the natural position of the pansy blossom it should be remembered that the pistil is directed downward, and the end of the stigma rests on the lower petal, with the stigmatic cup opening outward and away from the anthers. Between the two anthers, on the under side of the pistil, and at the end nearest the stigma, there is a V-shaped notch from which the pollen may readily escape when the flower is shaken by the wind or insects. Since the notch is immediately over the groove in the lower petal, the pollen falls into this groove and cannot unaided get into the stigmatic cup, since, as before stated, this cup opens away from the direction in which the pollen must fall. That the pansy pretty effectually prevents self-pollination the following results of some of Darwin's experiments along this line show. Two vigorous pansy plants were selected for the experiment. One was covered with a net so that the bumblebees could not get at the flowers, and the other was left uncovered. In the uncovered one 105 fine capsules were formed, while on the covered one only 18 were formed; and in these only a few good seeds developed; and Darwin states that even the few seeds formed were probably due to the agency of tiny insects that the net could not exclude.

In many other flowers in which both pistil and stamens are present, we find other devices for preventing self-pollination. Some of these are as follows: In apple and pear blossoms the stamens usually ripen at different times from the stigmas in the same blossom, so that self-pollination in such cases is impossible. Likewise, when stamens and pistils are in different flowers, as in the pumpkin, corn, and willow, cross-pollination is obviously necessary, if seeds are to be formed.

Moreover, in case cross- and self-pollination take place in a given flower, it has been proved that the pollen from another flower will usually grow down the pistil more rapidly than the pollen produced in the same flower, and so in such cases fertilization is more likely to result from cross-pollination than from self-pollination.

96. Cross-pollination by insects. — From our study of the pansy we learned that insects are attracted by bright colors and sweet odors. By many observations biologists have learned that most flowers with these characteristics are visited by insects, and that these animals carry pollen from blossom to blossom, thus insuring cross-pollination. Any one familiar with apple, pear, or other fruit trees has seen that at time of blossoming these trees are alive with buzzing bees, and fruit growers know that were it not for these insect visitors their fruit crops would prove a failure. Some plants (the squash, for example) have two kinds of flowers, one kind containing stamens, the other pistils. It is evident, therefore, from what we have already learned that pollina-

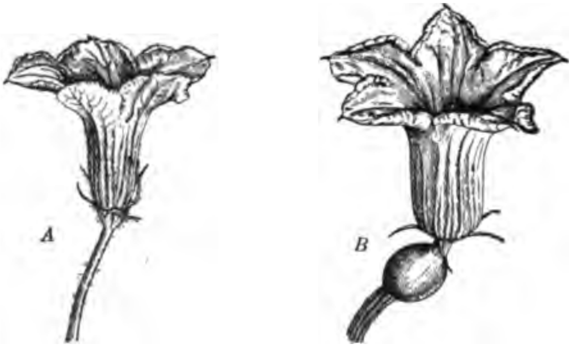

FIG. 32. — *A*, staminate squash blossom ; *B*, pistillate squash blossom. (Bailey.)

tion, fertilization, and the development of fruit and seeds could not take place in plants like these if there were not some means of transferring pollen from the *staminate flowers* to *pistillate flowers*. One has only to watch squash blossoms on a sunny day to know that bees visit them in great numbers and that their hairy bodies are dusted with yellow pollen as they fly from flower to flower.

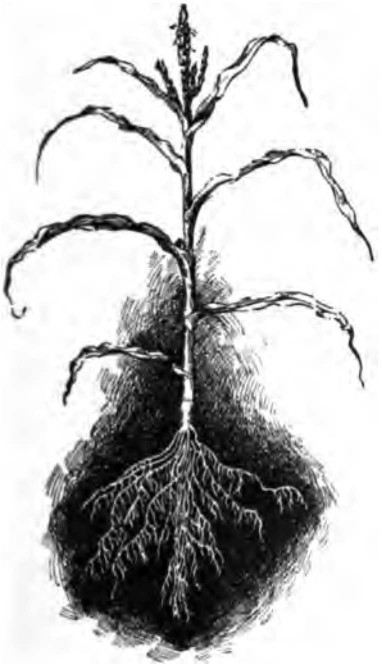

FIG. 33. — Corn stalk with "tassels" (staminate flowers) at the top. — (Duggar.)

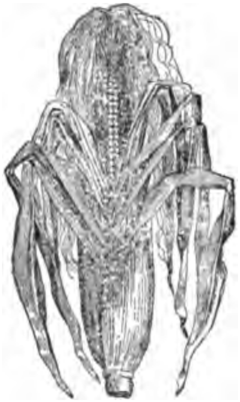

FIG. 34. — Developing ear of corn (pistillate flowers). — (Bailey.)

97. Cross-pollination by wind. — There are many plants, however, which have flowers without conspicuous color or odor; among these are the grasses, the corn, and many common trees like the oaks, birches, and pines. At the top of the corn stalk in midsummer develop the "tassels," and when these are shaken, they scatter great quantities of light, dry pollen. On another part of the plant the ears of corn develop. Each ear consists in part of clusters of pistillate flowers, and the threads of silk represent the styles of the pistils. Farmers know that a single corn plant, growing in a place apart from other corn plants, will not form vigorous ears. To secure a good crop, pollen must be carried from the tassels of one plant to the silk of another, and this is accomplished in a garden or a corn field by the wind. Much more pollen must be produced, however, by wind- than by insect-pollinated flowers, since in the former case a great deal more is wasted. Many wind-pollinated flowers, such as grasses, have feathery styles to catch and hold the pollen brought by the wind.

98. Summary and definitions.

Floral envelopes of a flower = calyx + corolla.

Calyx: composed of sepals (often green in color); principal use, to inclose and help protect the essential organs from cold, rain, or biting insects.

Corolla: composed of petals (usually bright colored); principal use to attract insects and so secure cross-pollination.

Essential organs of a flower = stamens + pistils.

Stamens: usually composed of filament and anther; use, to produce pollen grains, each containing a sperm-cell.

Pistil: usually composed of ovary, style, and stigma (or stigmas); use, to produce ovules, each containing an egg-cell, and to insure pollination, germination of pollen grains, and fertilization.

II. THE STRUCTURE AND FUNCTIONS OF FRUITS

99. Relation of fruits to reproduction. — We have already learned that the use or function of flowers is to insure the production of seeds. As is generally known, seeds are found in fruits. We are now to study several types of fruits.

100. Study of the bean or pea fruit. — Laboratory Study No. 46.

A. Outside of the fruit.

Study if possible young pods, well-developed pods, and pods that have dried; or charts may be used to show the developing pods.

1. Name and describe the structure which attached the pod to the plant.
2. The main part of the fruit or pod is the *pistil,* which in the bean or pea flowers consisted of *ovary, style,* and *stigma.* Which of these parts are found in the fruit you are studying? (Fig. 35.)
3. Bean and pea blossoms have calyx, corolla, stamens, and pistil. What parts of the flower are present in the fruit? What parts have disappeared?
4. Make a drawing, natural size, of the fruit you are studying in the position in which it hung on the plant. Label fruit-stalk, calyx (if present), and the parts of the pistil that you find.

B. Inside of the fruit.

Split the pod lengthwise into halves.

1. Carefully move one of the seeds in the pod; is it free from the pod, or is it attached?
2. (Optional.) The region of an ovary to which seeds are attached is called the *placenta* (as was also the case in the ovary of flowers). Locate the placenta in the fruit you are studying.
3. (Optional.) State whether or not you find any undeveloped seeds. Undeveloped seeds probably never were fertilized.

4. Draw, natural, size in the position in which the pod hung on the plant the opened fruit. Label wall of ovary, developing seeds (undeveloped seeds, if present), seed-stalk.

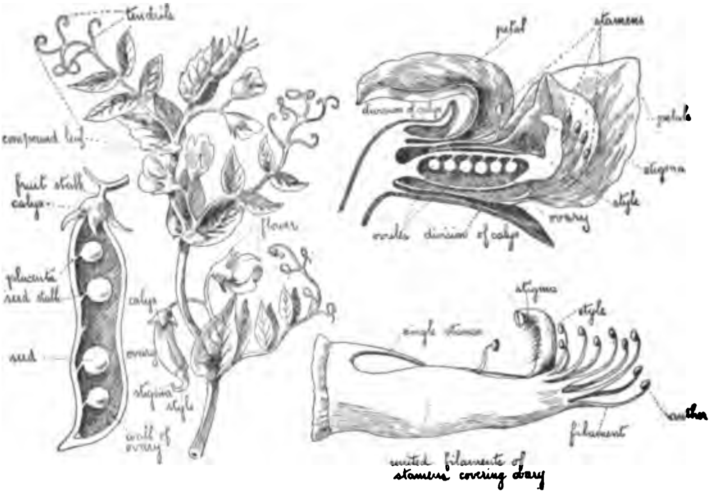

FIG. 35. — Development of the pea fruit from the pea flower. — (Drawn from Jung Chart.)

101. Study of the cucumber, Tokay grape, cranberry, or tomato fruit. — Laboratory Study No. 47.

A. Outside of the fruit.

1. All of the fruits named above are developed ovaries. Describe the shape and color of the fruit you are studying.
2. Make a drawing, natural size (or an inch in diameter in case the grape or cranberry is used). Label fruit-stalk (if present), ovary.

B. Inside of the fruit.

Cut a cross section of one of the fruits you are studying.

1. Carefully move one of the seeds within the fruit; is it attached or is it free?

2. Make a drawing, natural size (or an inch in diameter in case the grape or cranberry is used), of one half of the fruit, and show method of seed attachment.

3. (Optional.) Pinch a seed of one of the fruits between your thumb and forefinger. Is it hard or soft? Is it dry or slippery? Of what advantage are these characteristics?

102. Seed dispersal. — It is evident that stronger plants will be developed from seeds if the latter are carried some distance from the mother plant, for then they will not be shaded by the mother plant, and the young plants will have more light, air, food, and moisture, if they are not crowded together. We shall now study some of the devices by which plants secure the dispersal of their seeds.

103. Seed dispersal by wind. — Laboratory Study No. 48. Study one or more of the following fruits: —

A. *Winged fruits.*

1. The maple fruit.
   - *a.* Find the *fruit stalk*, the *two cells of the ovary* each containing a single *seed*, the *wing* attached to each cell of the ovary.
     Hold between yourself and the light a maple fruit in the position in which it hung on the tree, and draw it (× 2). Label fruit-stalk, cell of ovary, containing one seed, wing, veins of wing.
   - *b.* Hold one of the fruits some distance above the desk and let it fall. Describe the movements of the fruit in falling.
   - *c.* Of what use are the wings if the wind were blowing while the fruit is falling, or after the fruit has fallen to the ground?
   - *d.* Is the maple fruit a dry or a fleshy fruit?
2. The linden fruit.
   - *a.* Notice the wing-like attachment on the fruit-stalk. Do the linden fruits occur singly or in clusters?

Is the fruit hard or soft? Draw in the position on which it hung on the tree (× 2) the fruit that is given you. Label main fruit-stalk, wing-like attachment, single fruit stalk, fruit.

b. c. d. Answer questions given under 1 (above).

3. The elm fruit or ailanthus fruit.
   a. Notice the *fruit stalk*, the *single-celled ovary*, the *wing* about the ovary.
   Draw (× 2) one of the above-named fruits. Label fruit-stalk, ovary, wing.
   b. c. d. Answer questions given under 1 above.

B. *Tufted fruits* (*or seeds*).

1. The clematis, dandelion, thistle, or aster fruit.
   a. Find the tiny *seed-like ovary,* containing a single seed, and the *tuft of hair.* Draw (× 2) one of the fruits. Label ovary, tufts of hair.
   b. c. d. Answer questions under *A*, above.
2. The milkweed fruit and seed.
   a. (Optional.) Study Fig. 36. Describe the way the pod opens when it is ripe. Are the seeds many or few?
   Draw one of the fruits (pods) to show the method of opening. Label fruit-stalk, ovary, seeds, style.
   b. Examine one of the seeds that has been detached from the pod. Draw (×2) one of the seeds with its tuft of hair. Label seed, tuft of hair.
   c. Drop one of the tufted seeds out of an open window when a breeze is blowing or fan a seed in the laboratory. State your observation. What is one use of the tuft of hair?

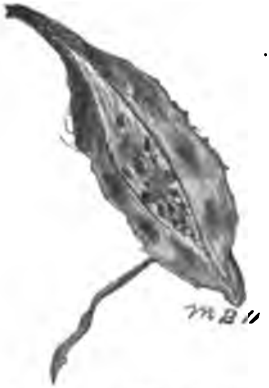

FIG. 36. — Milkweed pod opening.

104. Seed dispersal by animals. — Laboratory Study No. 49. Study one or more of the following fruits:

A. Burs and stickers.

1. Cocklebur.
   - *a.* Hold one of the fruits between yourself and the light. Do the hooks all curve toward one end of the fruit or in several directions?

     Notice the two larger projections at one end of the fruit. These are the *styles*. Draw (× 2) the outside of one of the cockleburs, showing the direction of the hooks. Label ovary, hooks, two styles (large prongs at one end of fruit).
   - *b.* Rub one of the cockleburs on a rough surface of your clothing and try to remove it. By what means does it cling to the cloth? How is a cow or other hairy animal adapted to disperse this fruit?
2. Burdock.
   - *a.* Each burdock consists of a large number of individual fruits. Hold the burdock to the light. In what directions do the hooks extend? Why is this an advantage in securing the distribution of fruits?
   - *b.* Answer questions under 1 *b* above.
3. Bidens (also called pitchforks or beggar's ticks).
   - *a.* Hold the fruit to the light or examine it with a hand magnifier. In what direction do the little barbs on the two prongs of the ovary extend? Why is this an advantage?

     Draw (× 2) one of the bidens fruits. Label ovary, prongs, barbs.
   - *b.* Answer questions in 1 *b* above.

B. Fleshy fruits. Suggested as home work.

1. In what ways are the seeds of apples, cherries, and of many other fleshy fruits protected while they are ripening?

2. Many fleshy fruits are dispersed by birds and other animals which are seeking food. How are these animals rewarded for doing this work?
3. How are the seeds of ripe peaches and cherries, for example, protected from injury?

105. Fruits and their classification. — If one were asked to give examples of fruits, one would doubtless give such forms as apples, cherries, and peaches. But it is doubtful if he would think of including among fruits, pea pods, pumpkins, chestnuts, and corn. To the botanist, however, these are considered to be just as truly fruits as the forms commonly thought of as fruits. Let us see why such diverse plant products as those just named are all included under the heading of fruits. Technically, *a fruit is a ripened ovary and its contents with any other part of the plant that is closely incorporated with it;* and since the forms named above are all ripened ovaries containing one or more seeds, it is evident that, strictly speaking, they must be classed with the fruits as much as apples and cherries.

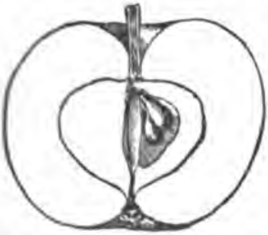

Fig. 37. — Lengthwise section of apple fruit, showing seeds attached to a central placenta. — (Bailey.)

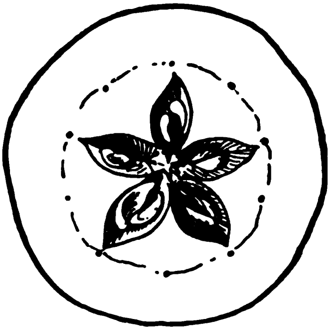

Fig. 38. — Cross section of apple fruit, showing seeds and their coverings which constitute the core.

Sometimes the flower contains a number of pistils which form a pulpy mass, such as the raspberries and blackberries (see Fig. 40); hence each of these so-called berries is composed of a number of separate fruits. Sometimes the end of the stem which bears the pistils becomes pulpy and juicy and the dry pistils are embedded in its outer surface, as is the case with strawberries (see Fig. 42). In other fruits the ovary may form a hard woody wall, as in the nuts like the chestnut (Fig. 39) and acorn, or the wall may be like a tough paper, as in the pods of peas and locusts (Fig. 43). In still other forms the whole ovary may become fleshy, as in the true berries, such as the cranberry, grape, and tomato. Or we may find a combination of a tough wall and a fleshy interior, as in the pumpkin, squash, and cucumber. In cherries, plums, and peaches the ovary forms two kinds of material, the inner very hard and stone-like and the outer pulpy. In fruits like the corn grain and the wheat kernel the ovary wall is so closely united with the coats of the single seed that these grains are commonly considered as seeds.

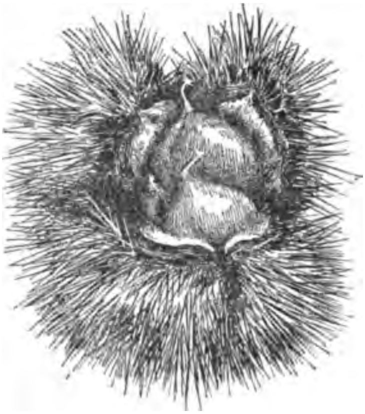

FIG. 39. — Chestnut fruits inside the chestnut bur. — (Bailey.)

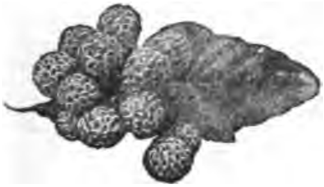

FIG. 40. — Raspberry fruits.

The facts just stated with regard to different kinds of fruits suggest a simple form of classification, based largely on the characteristics of the ovary walls. Thus, for instance, all those fruits, such as bean pods,

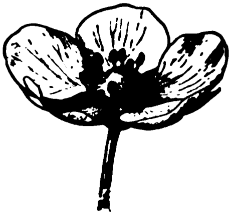

Fig. 41. — Flower of the strawberry. — (Bailey.)

grains, and nuts, in which the walls are dry at maturity, are called *dry fruits.* Those in which the walls are pulpy throughout, as in the tomato, are termed *fleshy fruits;* and those which are partly fleshy and partly stone-like, as in the cherry and peach, are called *stone fruits.*

Fig. 42. — Strawberry. — (Bailey.)

Another scheme for classifying fruits is based upon the fact that some fruits break open when ripe and scatter their seeds, while others remain closed. Examples of fruits of the first kind are the bean, milkweed, and pansy, and of those that remain closed are cherries, apples, and grains. Whether or not a fruit breaks open at maturity depends upon the character of the ovary wall, and this in turn determines, as we shall now see, the method by which its seeds are dispersed.

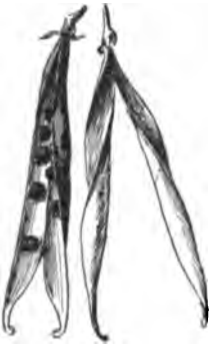

Fig. 43. — Pea pod. (Bailey.)

106. Home work on fruits. — Laboratory Study No. 50. (Optional.)

Classify the fruits with which you are familiar in a table like the following:

Name of Fruit	Dry Fruit	Fleshy Fruit	Stone Fruit	Open when Ripe	Closed when Ripe	Seeds Dispersed by Wind	Seeds Dispersed by Animals
Cherry			X		X		X

CHAPTER VIII

PLANT PROPAGATION

I. SEEDS AND THEIR DEVELOPMENT INTO PLANTS

107. Study of the bean seed and the development of the bean seedling. — Laboratory Study No. 51.

Materials: Dry bean seeds and seeds that have been soaked for 24 hours. Sprouted bean seeds and seedlings grown as follows: To secure early stages, put seeds that have been soaking for 24 hours between layers of wet blotting paper, or bury them in moist sawdust, and allow them to stand in a warm place for two or three days. For older stages of bean seedlings plant soaked seeds in boxes containing moist sawdust, sand, or earth. If some of these boxes are put in a warm place and others in a cool place all stages may be obtained in two to four weeks.

1. What difference do you notice in the size of the dry and soaked seed? How do you account for this difference?

   (Optional.) Half fill a bottle with dry bean seeds, and add water enough to fill the bottle. Allow the seeds to soak for 24 hours. How much do beans increase in size when soaked?

2. On one edge of a soaked seed find a *scar* called the *hilum*, which marks the place where the bean was attached to a small stem which connected it to the pod. Locate the hilum, and state what caused this scar.
3. Make a sketch about two inches long of the seed, showing the edge on which the scar is found. Label scar or hilum.

4. Pinch a soaked seed, and notice the opening near the hilum through which water is forced from the seed. This opening is called the *micropyle* (Greek, *micro* = tiny + *pula* = gateway).
   - *a.* Describe the position and appearance of the micropyle. What is the derivation of the word?
   - *b.* Sketch the micropyle in your drawing in 3 above.
5. Carefully remove the *seed-coat* from a soaked bean. All the structures within this seed-coat together form a little bean plant, called a *bean embryo.* Break off one of the two halves and make out the following parts of the bean embryo: 1) the two thickened halves of the bean called the *seed leaves* or *cotyledons;* 2) a little sprout, the *first stem* or *hypocotyl* (Greek, *hypo* = beneath + *cotyl* = cotyledon); and 3) the two tiny folded leaves forming the *first bud* or *plumule,* lying between the cotyledons.
   - *a.* State what you have done to show the parts of the embryo.
   - *b.* Name and describe each of these parts.
   - *c.* Place the cotyledon you have removed close to its point of attachment to the hypocotyl, and make a drawing about two inches long, showing all the parts named above, labeling each part.
6. Examine a bean seed that has just begun to sprout.
   - *a.* Name the part of the bean embryo that first breaks through the seed-coats.
   - *b.* Make a drawing about two inches long, to show the sprouted seed. Label.

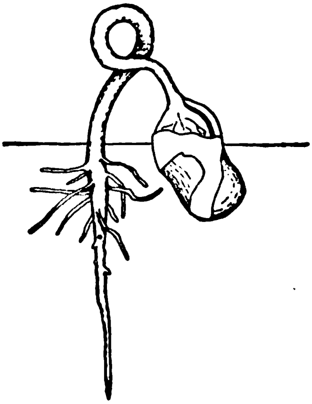

FIG. 44. — Germination of castor bean. — (Osterhout.)

7. Look at a pot of young seedlings that are just pushing their way above the surface of the soil or sawdust.
    - *a.* Which part of the embryo first appears above ground?
    - *b.* What is the shape of this part?
8. Study a whole seedling at this stage (see 7 above), from which one cotyledon has been removed.
    - *a.* Describe the changes that have taken place in each part of the embryo since the seed began to sprout.
    - *b.* Describe the position and appearance of the main root and its branches that appear in this stage.
    - *c.* Make a drawing, natural size, of a seedling at this stage and show by a horizontal line the ground level. Label each part.
9. Study a well-developed seedling, comparing it with the stages already drawn, and answer the following questions:
    - *a.* What changes in the size of the cotyledons do you notice as the seedling grows older? Most of the food for the early development of the seedling is furnished by the cotyledons; suggest, therefore, the cause of the change in size of the cotyledons, which you have noticed.
    - *b.* What parts of the developing embryo have changed in color during germination; how have they changed?

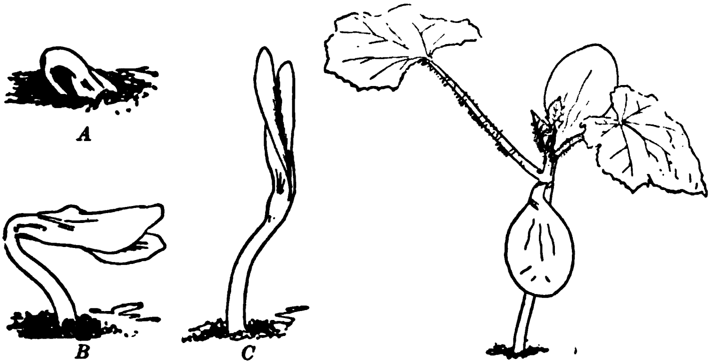

FIG. 45. — Stages in the development of the squash seedling. — (Bailey.)

c. What parts of the oldest seedling have developed from the plumule?

10. Draw the oldest stage of the bean seedling, and label main or *primary root,* root-branches or *secondary roots,* ground level, cotyledons (or scar left by cotyledons), hypocotyl, stem above cotyledons (*epicotyl*), leaves, terminal bud.

108. Study of the corn seedling and its development from the corn grain. — Laboratory Study No. 52. (Optional.)

Materials: Dry and soaked corn grains; seedlings of various sizes grown as described above for the bean seedling. Corn grains should be planted with the pointed end down.

The structure of the corn grain and the development of the corn embryo can be understood much more easily if the study of the corn seedling is made first, and later that of the corn grain.

A. Seedling just breaking ground.

1. Examine a pot of seedlings that are just pushing their way through the soil or sawdust, and study a seedling of this stage that is given you. All the parts of the seedling above the corn grain have developed from the first bud or plumule.

a. What is the shape of the part that first breaks through the soil?

b. Look for the *sheath leaf* surrounding the unfolding leaves, and trace it down to the ridge around the stem from which it springs. How does this sheath or first leaf of the plumule differ from the unfolding leaves? What is its probable use?

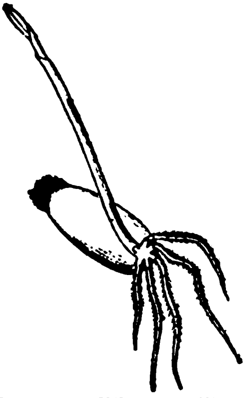
FIG. 46. — Wheat Seedling.

2. Observe the scar on the grain, showing where it was fastened to the cob, and notice the shape of the

grain at its opposite end. Does the plumule develop from the blunt end or the pointed end?

3. Make a sketch of the seedling (× 2) and label grain of corn, scar where grain was attached to the cob, stem of plumule, sheath leaf, unfolding leaf, main root, rootlets, soil line.

B. Corn grain just sprouting.

1. Examine a corn grain that has just sprouted. Recall to mind the end of the grain from which the main root grew. (If you are not sure, look at your drawing, or better yet the seedling.)
   - *a.* What part of the little corn plant breaks through the covering first?
   - *b.* What other part of the embryo shows signs of growth?
2. Remove the thin covering from the grain, and observe an oval body embedded in the corn grain. This is the little corn plant or embryo. How does the embryo differ in color from the rest of the grain?
3. The oval-shaped body from which the root and plumule seem to spring in the grain of corn is called the *cotyledon*. The remainder of the grain is *endosperm*, which is the food material for the development of the embryo. Make a sketch of the seedling at this stage (×2) and label single cotyledon, plumule, endosperm or food material, main root.

C. Corn grain.

1. Very carefully scrape away a little of the surface of the cotyledon of a dry or soaked grain till the other parts of the little plant or embryo come into view. Make out the plumule and main root.

   Sketch the corn grain and label cotyledon, plumule, tiny root, food material around the plant (endosperm).
2. Cut a corn grain in such a way as to divide the embryo and endosperm lengthwise in half. Put one half in iodine. Where in the corn grain is starch present? Where is it absent?

D. Corn seedling well advanced.

1. What changes have taken place during the development of the seedling in the roots? in the plumule?
2. How does the veining of the leaves in the corn plant differ from that in the leaves of the bean plant?
3. Where do you find *aërial* or *air roots* on the corn seedling? (Roots growing above ground are aërial roots.)
4. Pinch the grain between your fingers. What changes do you notice in the amount of food material? How can you account for these changes?
5. Make a sketch of the seedling and label corn grain, cotyledon, stem, leaves, aërial roots, soil roots.

109. Suggestions for growing seedlings at home. (Optional.)

A. Window box. — Secure a wooden box at least six inches in depth, and of a convenient size to place in front of a south window, if you have such a window at home. Nearly fill the box with rich earth which has been finely pulverized or sifted. If possible, mix in thoroughly some well-rotted manure and a tablespoonful of prepared fertilizer. Soak your seeds for twenty-four hours, and plant them at a depth equal to four times the thickness of the seeds. Cover the seeds with dirt, press it down firmly, and sprinkle with water till the earth is thoroughly moistened to a depth of at least four inches. See that your garden is kept as nearly as possible at a temperature of 70 degrees. Add enough water day by day to keep the ground moist.

B. Tumbler garden. — Secure several pieces of blotting paper or other porous paper, and cut it about as wide as the tumbler is high. Wet the paper and roll it into a hollow cylinder that fits inside the tumbler. Between the blotting paper and the glass place the soaked seeds with their hilums in several different positions. Fill the interior of the tumbler with wet sawdust, cotton, or crumpled paper. Cover the tumbler loosely and keep the contents moist, and at a temperature of about 70 degrees.

C. Glass-plate garden.[1] — Secure two pieces of glass about 5 × 7 inches (picture negatives cleaned in hot water are admirable for this purpose). Upon one of the glasses put a layer of wet cotton wadding about half an inch thick. Arrange the seeds (which have been soaked for 24 hours) with their hilums in several different positions, and place on top of them the second plate of glass. Tie strings about the two glasses, and stand the "garden" in about an inch of water. The water will rise between the glasses and keep the developing seedlings moist. After the seeds have begun to sprout, turn the "garden" so that it rests on another edge, and note the effect on direction of growth of the hypocotyl.

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[1] The authors are indebted to Dr. Cyrus A. King, Head of Department of Biology of Erasmus Hall High School, Brooklyn, N. Y., for this method of germinating seeds.

Observations to be made on the development of each seed

1. What part of the seedling first appears above ground? (Make drawings.)
2. Does this part come up straight or in the form of an arch?
3. What kind of veining is found in the leaves?
4. How many cotyledons are present, and what is their use?
5. In what direction does the main root tend to grow? the secondary roots?

110. Comparison of seeds and seedlings. — Study No. 53. (Optional.)

Soak and plant at home as directed under *Materials* (**107**), several kinds of seeds. Study the seeds and seedlings, and fill out in your note-book a table like the following:

	BEAN	PEA	SQUASH	CORN, ETC.
Number of cotyledons . . .	——	——	——	——
Position of stored food . . .	——	——	——	——
Kinds of food present . . .	——	——	——	——

Function of cotyledons . .				
(Storage of food)	——	——	——	——
(Absorption of endosperm)	——	——	——	——
(Foliage)	——	——	——	——
Method of breaking ground .				
(By arched hypocotyl) . .	——	——	——	——
(By arched plumule) . .	——	——	——	——
(By erect pointed plumule)	——	——	——	——
Veining of foliage leaves . .				
(Netted)	——	——	——	——
(Parallel)	——	——	——	——

111. Nutrients stored in corn grains for the use of the seedling. — Laboratory Study No. 54. (Optional.)

Grind with a mortar and pestle some corn grains till a fine meal is prepared. Test for each of the food substances and fill out in your note-book a table like the following:

Name of Nutrient	Chemical Used	Result	Conclusion
Starch . . .	——	——	——
Grape sugar .	——	——	——
Protein . . .	——	——	——
Fat[1]	——	——	——

112. Of what importance is the endosperm in the development of corn seedlings? — Laboratory Study No. 55. Home work or demonstration.

Soak twenty-four or more corn grains over night. Carefully remove from half of them all the endosperm (food materials) from around the embryo corn plant. Plant the corn grains and the corn embryos in rich soil, covering both with the same depth of earth, and marking the location of the two sets. Put them in a warm place.

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[1] To test for fat, put some of the cornmeal into a test tube, add some ether, shake frequently, and let the tube stand for a time. At the end of twenty-four hours pour off the clear liquid upon pieces of glazed paper. After the ether has evaporated, hold the paper to the light. *Be careful* not to hold the ether near a flame.

1. Describe the preparation of the experiment.
2. At the end of two weeks state the number of each group of seedlings that have pushed through the soil.
3. What difference in the size of the two sets of seedlings do you notice at the end of two weeks? at the end of three weeks?
4. What has this experiment taught you?

II. OTHER METHODS OF PLANT PROPAGATION

113. Grafting. — The method often adopted by fruit growers to produce new and better varieties is that known as *grafting.* This method of plant propagation may be carried on in the following manner. A young shoot, known as the *scion* (Fig. 47, *A*, *b*), is cut in an oblique direction from a tree, the fruit of which is desired, and a similar oblique cut is made across the twig of another tree, called the *stock* (Fig. 47, *A*, *a*), of a related kind. The two freshly cut surfaces are then closely applied to each other, and the scion and

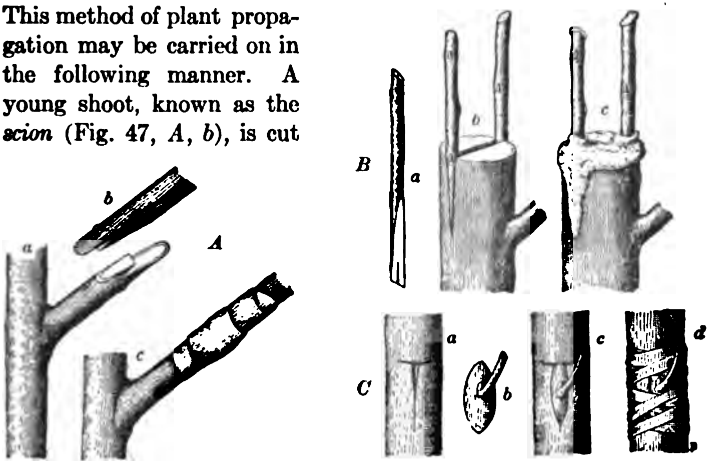

FIG. 47. — Methods of grafting.

stock are bound together by grafting wax (Fig. 47, *B*, *c*), which is put around the outer bark to hold the two pieces in place and to prevent evaporation. In this way the cambium layers of the two plants are brought into close contact and soon unite. The ducts of the stock likewise join those of the scion, and so sap is transmitted to the grafted twig, which grows and develops its fruit as though it were still a part of the plant from which it was taken. There are many different ways of cutting and binding the twigs together, and even buds may be used as scions (Fig. 47, *C*, *b*). But the principle is the same in every case.

Grafting is of necessity employed in producing new plants of seedless grapes or oranges. It is also frequently adopted to combine the desirable characteristics of two different plants. For example, when the vineyards of France were being destroyed by an insect that attacked the roots, the fruit-growers overcame the difficulty by grafting the wine-producing scions upon the more vigorous and resistant nutritive stock of grapevines introduced from America.

114. Slips, runners, and layers. — Another method of producing new plants is that of cutting twigs of plants that are desired, and placing the lower end of the stems in moist sand. Roots soon develop on these so-called *slips*, and the new plants thus formed can then be transplanted into good rich soil. Any one who has seen a vigorous strawberry plant knows that it sends out a lot of slender stems which grow so rapidly that they are known as *runners*. When a portion of one of these runners lies upon the surface of moist soil,

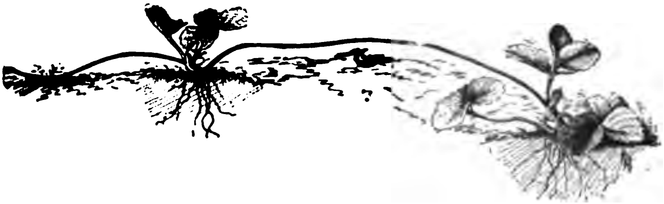

FIG. 48. — Strawberry plant with runner. — (Bailey.)

roots are formed as in the case of slips, and when they are firmly established, the connection with the parent plant may be severed, and thus a new strawberry plant secured. Still another method of propagating plants is known as *layering*, which may be accomplished in raspberry or blackberry plants by burying the tips of branches in the soil, thus inducing the production of roots. The new plant can then be severed from the parent.

115. Tubers. — New potato plants are commonly secured, not by planting potato seeds, but by cutting into pieces a potato which is a fleshy underground stem or *tuber*, each piece having one or more "eyes," and putting these into the ground. In each eye is a bud, and when this sprouts it develops stems and leaves above ground, the new plant thus formed getting a considerable amount of nutrition from the food stored in the tuber during the preceding season.

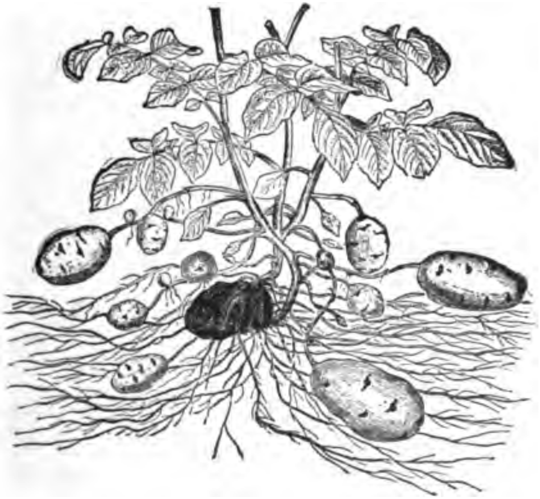

FIG. 49.—Potato plant and tubers grown from dark colored potato in center. — (U. S. Dept. Agriculture.)

116. Bulbs. — Still another method of propagating plants is by means of *bulbs*, which, in the onion, for example, consist of a short, thickened underground stem, to which are attached many layers of thickened parts of leaves known as *bulb-scales*. Frequently, as in the tulip and hyacinth, after the food stored in the bulb has been used in the early spring to develop stem, leaves, and flowers, the nutritive organs store away food for another season by producing new bulbs close to the old one.

117. Home bulb culture. — (Optional.)

Few plants are easier to cultivate or give greater satisfaction, especially in winter, than those that grow from bulbs. Secure a few tulip, hyacinth, or narcissus bulbs and bury them in pots of rich earth. Water them well and put them in a dark, cool place for four to six weeks, until the roots appear through the opening at the bottom of the pot. Then put them in a warm, sunny place, keep them well watered, and the flowers will appear in a few weeks.

III. CONDITIONS THAT ARE ESSENTIAL FOR THE GROWTH OF PLANTS

118. The five essential conditions for plant growth are the following: (1) moisture, (2) favorable temperature, (3) air, (4) light, (5) food. We have already shown the necessity of air for the germination of seeds (**79**) and for the liberation of energy (**76**). The use of the food stored in the corn grain for the corn embryo was also demonstrated in **112**. We have also proved that green plants do not manufacture carbohydrates in the absence of sunlight (**30**). We can likewise show experimentally the relation of moisture and temperature to the germination of seeds and to the growth of plants.

119. Relation of moisture to germination and growth. — Laboratory Study No. 56. (Optional.) Suggested as home work.

Secure three tumblers of same size (tin covered jelly-tumblers are very satisfactory). In the bottom of each put a piece of sponge about half the size of the fist (a wad of cotton or paper will answer). Label the first tumbler No. 1, and place upon the sponge 10 pea seeds that have been soaked for 24 hours. In the second tumbler (labeled No. 2) put 10 soaked peas, and add enough water to come nearly to the top of the sponge. Put 10 soaked pea seeds into the other tumbler (No. 3), and add sufficient water to cover all the peas. To prevent the evaporation of the water, cover the three tumblers, and place them side by side in a moderately warm temperature (65°–70° F.), and label each "Please do not disturb."

1. Which one of the five conditions (enumerated in **118** above) is different for the three groups of seeds?
2. Name all of these conditions which are practically the same for the seeds in all three of the tumblers.
3. At the end of a few days compare the seeds in the three tumblers. What percentage of the seeds in each of the three tumblers has germinated?
4. State clearly your conclusion as to the relation of water to the germination of pea seeds.
5. Allow the three tumblers to stand side by side in a warm, light place for several weeks. Describe the changes that take place in each tumbler, and state your conclusion as to the relation of moisture to the growth of pea plants.

120. Relation of temperature to germination and growth. — Laboratory Study No. 57. (Optional.) Suggested as home work.

Prepare three tumblers with sponges (cotton or paper) as in **119** above, putting in water enough to come nearly to the top of the sponge in each dish. In each tumbler place 10 soaked peas, and put on the covers. Label No. 1, No. 2, and No. 3. Set tumbler No. 1 in the refrigerator or in some place where it will not freeze. Keep Tumbler No. 2 at the temperature of the living room. Place No. 3 where the temperature is over 100°. Make sure that all tumblers have about the same amount of light by covering each with black paper or a cloth. By the aid of a thermometer find and record the temperature of each place where you put a tumbler. Each day look at the tumblers, and if necessary add enough water to keep the level the same in all three.

1. Which one of the five conditions named in **118** is different for the three groups of seeds?
2. Name all the conditions which are practically the same for the seeds in all three of the tumblers.
3. At the end of a few days compare the seeds in the three tumblers. What percentage of the seeds in each of the three tumblers has germinated?
4. State clearly your conclusion as to the relation of temperature to the germination of pea seeds.
5. Allow the three tumblers to stand in the three different temperatures for several weeks. Describe the changes that take place in each tumbler, and state your conclusion as to the relation of temperature to the growth of pea plants.

121. The soil. — "From the soil all things come; and into it all things at last return; and yet it is always new, and fresh, and clean, and always ready for new generations. This soft, thin crust of the earth — so infinitesimally thin that it cannot be shown in proper scale on any globe or chart — supports all the countless myriads of men, and animals, and plants, and has supported them for countless cycles, and will yet support for other countless cycles. In view of this achievement, it is not strange that we do not yet know the soil and understand it; and we are in a mood to be patient with our shortcomings." [1]

Even a casual examination of the soil in any region shows that it has a complex structure. Usually it is composed of some coarse particles known as *gravel*, finer grains called *sand*, and still more minute ingredients, the *mud* or *clay*. The relative proportions of these constituents determine whether the soil is a gravelly soil, a sandy soil, or a clayey soil. The soil particles to which we have referred supply the mineral ingredients needed by plants in the form of soil-water. But soil, to be fertile, must contain a considerable quantity of *vegetable mold*, the so-called *humus*, a dark brown or black substance produced by the decay of vegetable matter. This is the reason that florists mix with the dirt in their flower-pots a handful of material obtained from the floor of the forest (see frontispiece), where leaves have fallen and decomposed year after year.

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[1] Bailey's "Cyclopedia of American Agriculture," Vol. I, "Farms," p. 323.

122. Moisture. — If the student has tried the experiment in **119**, he will have been convinced that the amount of moisture supplied to seeds or plants has a great deal to do with their development. Soils in very dry or arid regions are deficient in water, and this must be supplied by *irrigation*. In semiarid regions proper methods of tillage, as we shall see, will do much to keep the soil in a proper condition for plant growth, so far as moisture is concerned. Very moist or "heavy" soils, on the other hand, are unfavorable for the growth of most plants, and so the excess of water must be removed by *drainage*.

Reviewing some of the facts already learned, we see that a large supply of water must be secured by plants from the soil, because —

"1. A living plant contains a large proportion of water — generally more than 75 per cent of its weight.

"2. Large quantities of water must pass through the plant in order that the food solution in the soil may be carried to the leaves, and the substances that it contains may be converted into organic matter. This water loss takes place by transpiration from the leaves and growing shoots.

"Careful and extended experiments in this country and Europe have shown that 300 to 500 tons of water are taken from the soil by the various crops for each ton of dry substance produced."[1]

123. Relation of the soil to air. — When the interstitial spaces between the particles of soil are not filled with water, or when they are only partly filled, they contain air. The air which circulates in the soil differs in composition from the air above the surface. As a rule, the soil air contains less oxygen and more carbonic acid (CO_2), ammonia, and vapor of water. The increased amount of carbonic acid and ammonia have their origin in the organic matter or humus. A soil is not in the best condition for the production of crops unless there is within its depths a free circulation of air. This is true because oxygen in the soil is as essential for the life of the plant as it is for the animal. . . .

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[1] Bailey's "Cyclopedia of American Agriculture," Vol. I, "Farms," p. 353.

"When the soil is full of water to within a few inches of the surface, there can be no circulation of air among its particles. Adequate ventilation can be provided for such a soil only by drainage. Drainage ventilates the soil by lowering the ground water three or four feet, and thus makes it possible for the roots of plants to penetrate soil more deeply. In time these roots die and decay and afford passageways throughout the soil for the ready movement of the air."[1]

124. Relation of soil to heat. — The influence of the temperature of the soil on crop production is a factor of considerable importance. The life processes of a plant are practically suspended below a certain minimum temperature, which is about 40 degrees Fahrenheit for most cultivated crops. Above this temperature all the vital activities, as germination and growth, increase until the optimum is reached. Above this point these life processes decrease in activity until the point is reached when they cease. The soil is a great factory that has its production vastly increased as the temperature rises. . . . The minimum temperature at which corn germinates and also the minimum for its growth is 48° or 49° F. Its optimum is about 93° F. . . .

"The sources of the heat of the soil are the internal heat of the earth, the sun, and decaying vegetable matter. It is difficult to estimate to just what extent the internal heat of the earth, which itself is very great, affects the temperature near the surface of the earth. However, the amount of heat from this source is insignificant, is a constant factor, and is entirely beyond the control of man.

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[1] Bailey's "Cyclopedia of Agriculture," Vol. IX, "Farms," p. 357.

Decaying organic matter furnishes some heat to the soil. For example, manure heats the soil to a limited extent when it is spread on the surface and plowed in. . . . The sun is by far the most important source of heat for the soil. When its rays are nearly vertical there is tropical heat; when its rays are withheld, the land is locked in snow and ice. The heat received at the surface passes downward by conduction."[1]

125. Cultivation of the soil. — A moment's thought will convince us that since all the food of man is ultimately derived from plants, any measures that tend to improve crops and reduce the cost of crop production are of vital interest to all of us. In the past, before much was known in regard to scientific principles, farmers put their seeds in the ground, cultivated them relatively little, and trusted Nature to do the rest. In recent times, however, man has learned a great deal in regard to soils, crops, and methods of cultivation, so that the modern farmer is often able to double the yield of a given area. The investigations of the National and State Departments of Agriculture have done much to make farming a science, and the future will doubtless see far greater improvements.

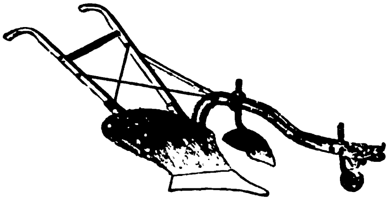
FIG. 50. — A plow.

For the cultivation of plants the first requisite is a suitable preparation of the soil. This involves, in the first place, plowing, which turns under any weeds or other plants that may have grown there before and which prepares for the work of the harrow, an implement which pulverizes the soil so that ready penetration of the roots of the growing plant is possible. In small garden plots this work is done by the use of spades, hoes, and rakes. It is often found necessary to add well-rotted manures to increase the humus of the soil and chemically prepared fertilizers, which furnish available mineral food for the crops. We have already called attention to the necessity of proper drainage of the soil before crops are planted (**122**). Scientific investigation has demonstrated, too, that frequent and thorough stirring of the soil is most important not only to prevent the growth of weeds, but also, and this is even more essential, to conserve the soil moisture, and insure proper aëration of the roots. It has been found that it is possible to produce large crops on semiarid land if the top-surface of the ground is kept in a thoroughly pulverized condition. This is the so-called method of " dry farming."

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[1] Bailey's "Cyclopedia of American Agriculture," Vol. I, "Farms," pp. 355, 356.

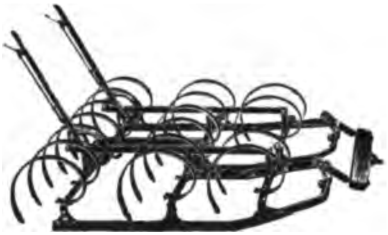

Fig. 51. — A harrow.

IV. The Struggle for Existence and its Effects

126. Variation among plants. — We have all heard the common expression "as nearly alike as two peas." In reality, however, if our powers of observation were sharp enough, we should probably find that no two peas are exactly alike in shape, color, size, and weight. The plants grown side by side from any two peas would also vary in height, in number and position of leaves, and in the number and vigor of flowers and seeds. In other words, as every human being has certain distinguishing characteristics, so, too, we should bear in mind that every individual plant, however small, shows certain differences or *variations* from every other individual of its class.

127. The numbers of seeds produced by plants. — A second fact which is evident to all is that plants produce an enormous number of seeds. Suppose we consider the case of a vigorous pea-vine. In the course of a season it should produce at least 20 pods, each containing at least 5 seeds. Hence, at the end of a single season, one pea seed would, if conditions were favorable, have multiplied itself 100 times. If each one of these seeds were to be planted where it had plenty of moisture, light, food, air, and favorable temperature, it likewise should give rise to 100 seeds, and so at the end of the second season we ought to have 100 × 100, or 10,000 pea seeds, all propagated from a single pea seed. Simple multiplication shows us that at the end of five years a moderately prolific plant like the garden pea would have given rise, had all conditions been favorable to 10,000,000,000 new seeds. Bergen has made a patient count of the number of seeds produced by an average morning glory plant, and finds it to be rather more than 3000; hence, at the end of the fifth year, if such a rate of reproduction were

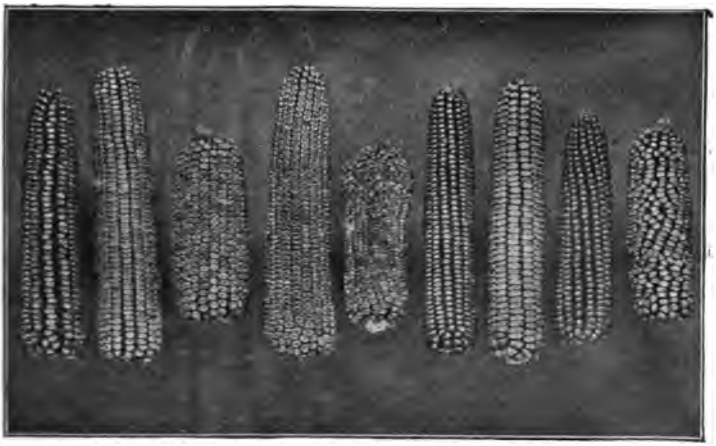

Fig. 52. — Variations in the corn ears produced in a single field. — (Courtesy of Dr. E. M. East, Bussey Institution, Harvard University.)

to be continued, there would be 243,000,000,000,000,000 morning glory seeds.[1]

It is evident, however, that no pea vine or morning glory plant, if left to itself, would be able to produce anything like the number of seeds we have named, for otherwise at the end of a short term of years there would not be room on the whole surface of the globe for any other kinds of plants than these. As a matter of fact, the number of individuals of a given kind of organism does not vary much from year to year. In the first place, many seeds are eaten by birds and other animals. Again, many other seeds are not carried to a place where they find all the conditions that are essential for germination (**118**). Still other seeds, even if planted in good soil and in favorable surroundings, fail to germinate. Because of the great losses of seeds in one or the other of these three ways, we can get some idea of the reason why plants must produce a great abundance of seeds if their kind is to be perpetuated.

128. The struggle for existence among plants. — But even if seeds finally germinate and get a foothold on the soil, a great many of the plants thus started will never reach maturity and ripen their seeds. In the first place, each plant is struggling to lift up its leaves

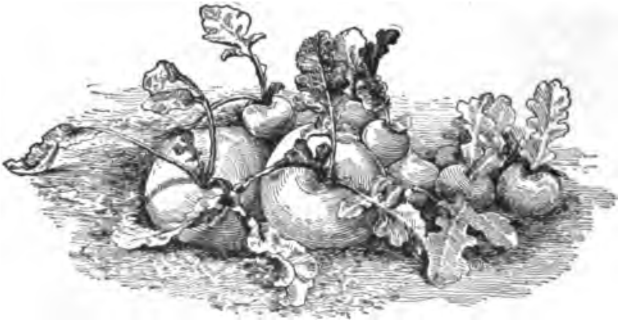

FIG. 53. — The struggle for existence and the survival of the fittest among turnips.

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[1] See Bergen's "Essentials of Botany" (1910), p. 202.

to the light and air, and those that are most vigorous usually get above and shade the others. Again, the supply of water and mineral food in the soil of a given area is limited; hence, plants that cannot get what they need are dwarfed and finally starved to death. In the third place, injurious insects destroy an enormous amount of vegetation, the loss of cultivated crops alone from this cause being estimated at $700,000,000 annually. Frosts, dry seasons, heavy rains, and fungous diseases are other important factors in the life of many plants. And so if we were able to see what is actually going on in each square foot of the earth's surface, whether of forest,

FIG. 54. — Charles Darwin.

field, or meadow, we should doubtless witness a life and death struggle for existence (1) between individual plants, of the same kind, (2) between individual plants of different kinds, and (3) between plants and animals.

Charles Darwin in his great book on the "Origin of Species," published in 1859, — a book which has doubtless influenced human thought more than any other book of modern times, — closes his chapter on the "Struggle for Existence" with the following words: "When we reflect on this struggle we may console ourselves with the full belief that the war of nature is not incessant, that no fear is felt, that death is generally prompt, and that the vigorous, the healthy, and the happy survive and multiply."[1]

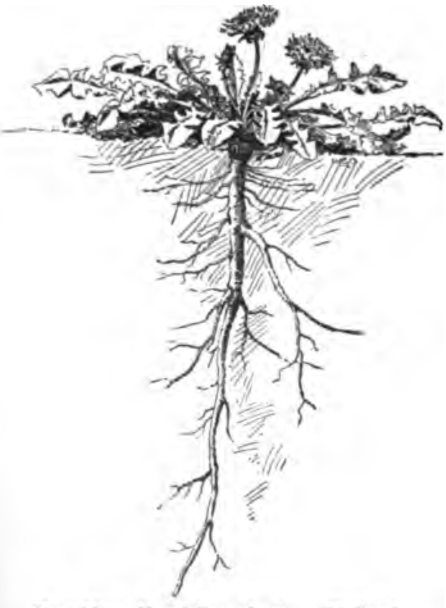

FIG. 55. — Dandelion plant. — (Bailey.)

129. The survival of the fittest. — We have seen in our study thus far (1) that no two individual plants even of the same kind are exactly alike, (2) that enormous numbers of seeds are produced by plants, and (3) that there is inevitable competition or struggle for existence. The question, then, that confronts us is this: Which of the many competitors will survive in the struggle, reach maturity, and finally reproduce themselves? Obviously those individual plants that vary from the rest in such a way that they can best adapt themselves to their surroundings. Let us see, for instance, why certain weeds like the dandelion are so common a nuisance on our lawns. In the first place these weeds have fleshy roots that reach deep down into the soil, thus helping the plant to get and keep a stock of moisture and food. In the second place the reserve supply of nutrition stored in these roots enables the plants to put forth leaves and flowers in early spring, and so to get a good start ahead of their competitors. Again, their short stems and tough leaves can be trampled upon without killing the plant. Insects and fungous diseases, for some reason, do not seem to attack them. And finally dandelions produce a large number of tiny seed-like fruits, each one of which is provided with a delicate tuft of hair which a puff of wind will carry for a considerable distance, thus insuring a wide dispersal of its seeds. In nature, then, plants like the dandelion, pigweed, and thistle have survived in the struggle for existence, because they are best fitted to their surroundings.

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[1] Darwin's "Origin of Species," p. 72.

V. THE IMPROVEMENT OF PLANTS BY MAN

130. Artificial selection of favorable variations. — In the preceding pages attention was frequently called to the fact that plants show a tendency to vary more or less from each other. Now it has been found that in a state of cultivation this tendency becomes even more pronounced. A watchful farmer will often find that in his cornfield one group of individuals ripens sooner than the rest, and so if he wishes to sell earlier corn, he selects and plants next year corn grains derived from plants that have varied in this direction. Again, he may notice that the ears on certain stalks are larger and ripen more kernels (see Fig. 52); these the crop-raiser who uses his brains would select for seed in order to increase his yield per acre. Variations in many other directions might be chosen by the successful farmer which would add immensely to the value of his crops. It is estimated that if every farmer were to select his seed carefully, the corn production in the United States, which at present is about $1,000,000,000, in a short time would be increased 10 per cent, which would add $100,000,000 to our annual income.

131. Artificial crossing of related species. — Not only can man secure new varieties of plants by watching for favorable variations and perpetuating them from year to year, but he can actually be *instrumental in producing new kinds of plants.* This process is known as *plant breeding.* It depends fundamentally on the principles we learned in treating of cross-pollination in flowers. Let us illustrate plant breeding by the following account of the work which has been done for the U. S. Department of Agriculture by Dr. H. J. Webber of Cornell University.[1]

In the winter of 1894–1895 a heavy frost destroyed practically every orange tree in the northern and central part of the State of Florida. The loss was over $75,000,000. The problem that confronted the orange growers of the State was that of starting their groves anew and if possible of preventing a repetition of such an experience by planting a more hardy kind of orange tree. Dr. Webber, in casting about for such orange trees, finally chose a type called the trifoliate orange (Fig. 56) often used for an ornamental shrub, and one that would not be killed by winters as far north as Philadelphia. The fruit of this tree, however, is small, bitter, and worthless for eating purposes. His task, therefore, was to combine the characteristics of a juicy, sweet-flavored fruit of the ordinary Florida orange tree with the hardy, cold-resistant character of the trifoliate type. He proceeded in this fashion:

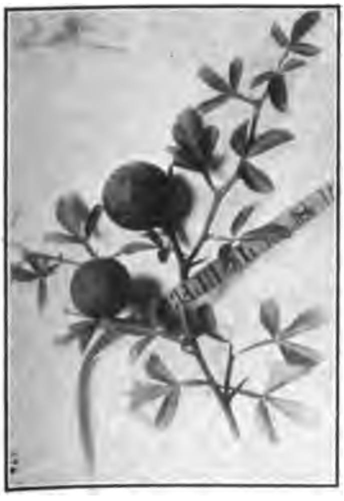

FIG. 56. — Spray from trifoliate orange, showing leaves and fruit.

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[1] See Year-books of U. S. Department of Agriculture, 1904, 1905, 1906.

From the flower-buds of one type of orange trees he removed all the stamens before blossoming time, and then covered the pistils with paper bags to prevent the visit of insects bringing pollen. A second set of buds on trees of the other type were likewise covered with paper bags to prevent possible mixing of pollen by insect visitors. When the stamens of one kind of orange blossoms and the pistils of the other kind had matured, the bags were carefully removed, and the pollen of one variety was dusted over the pistil of the other (see **87**). The paper bag was then replaced over the artificially pollinated pistil, and the latter left to ripen. Fruits

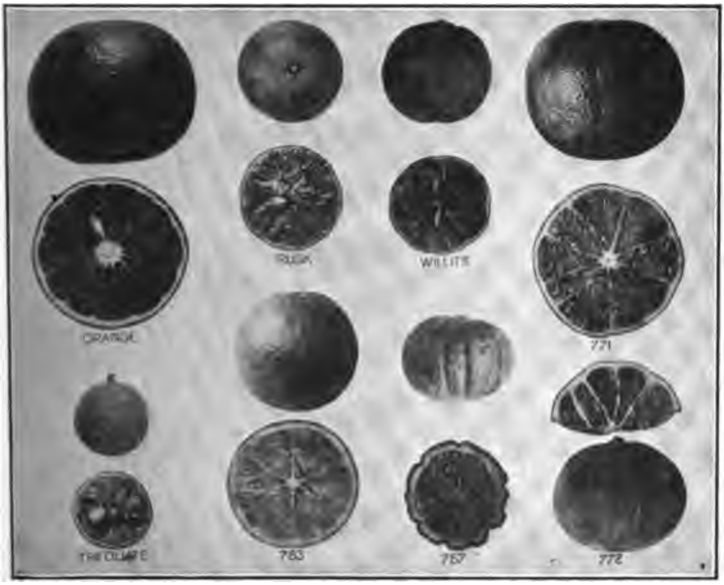

FIG. 57.—Fruits of two parent plants (orange and trifoliate) at left. Six types of hybrid fruits (Rusk, Willits, 783, 771, 772, 767) developed by cross-pollination from the parent plants, all being good fruits except 767, which proved to be worthless. Compare seeds and pulp in various sections.

formed by the cross-pollination of two different kinds of plants are known as *hybrid fruits*. The orange hybrid fruits thus developed were sent to Washington, where the seeds were removed and planted in greenhouses. When the young hybrid trees were about a foot high, they were sent to Florida and grown in a garden of the Department of Agriculture.

After a great many experiments in crossing the two kinds of oranges, and after rejecting hundreds of plants that proved to be worthless, Dr. Webber has succeeded in producing a type of tree that will withstand the winters of regions from three hundred to four hundred miles north of the present orange-growing section of Florida, and which will also produce a valuable, juicy fruit. These new fruits, which have been named *citranges*, make a delightful citrangeade and may be used in making pies, cakes, marmalades, and the like. In a similar way Dr. Webber has produced new varieties of tangerines, pineapples, cotton plants, and grass for hay.

The work of Luther Burbank[1] in California has likewise resulted in astonishing colors and sizes of pinks and poppy blossoms, in plums and peaches of great size, and in entirely new plants like the "pomato," produced by crossing the potato with the tomato.

132. Some of the valuable crops of New York State.[2] — New York ranks first of all the States of the Union in the production of the following crops:

NAME OF CROP	ANNUAL VALUE OF N. Y. CROP	FRACTIONAL PART OF U. S. CROP
Hay	$69,027,200	$\frac{1}{8}$
Potatoes	20,996,900	$\frac{1}{8}$
Other Vegetables	25,756,430	$\frac{1}{9}$

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[1] See "New Creations in Plant Life," by W. S. Harwood.

[2] The authors are indebted to Professors of Cornell University, for the use of the figures recently compiled.

(Since dairy products are directly dependent on agricultural conditions, they are also included in this tabulation.)

Dairy Products	$55,474,155	$\frac{1}{9}$
Milk	36,284,833	$\frac{1}{5}$

In spite, however, of its preëminence among the States in the production of the crops just named, experts tell us that the average yield per acre throughout the State is probably less than half what it should be or might be if more intelligence were used by the average farmer. The following quotation from an investigation made among 1303 of the farmers in the vicinity of Cornell University, near the center of the State of New York, shows in a striking way

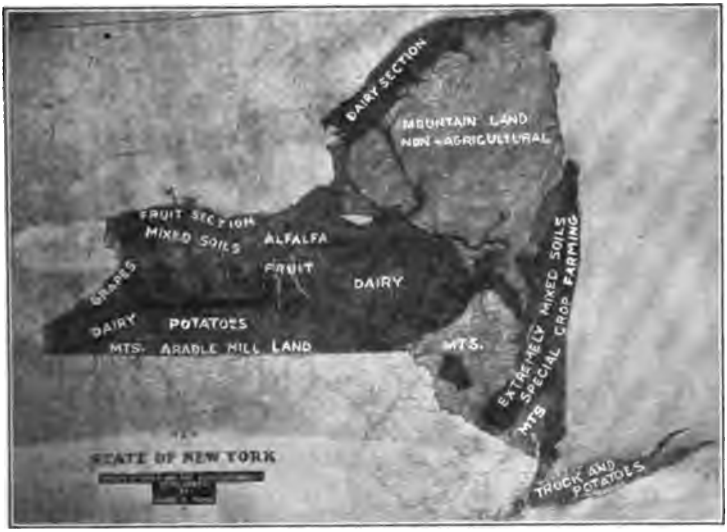

FIG. 58. — Map of New York State, showing the crops grown in various areas. — (Courtesy of Prof. E. O. Fippin, of Cornell University.)

the commercial advantage of even a high school education. "Of the owners, those who went only to district school made an average labor income of $318. The average labor income of high school men was $622. Of the more than high school men (*i.e.* college, normal, or agriculture courses) it was $847. The differences are emphatic. The labor income of the high school farmers is $304 greater than that of the district school men. This would be 5 per cent interest on $6080. In other words the high school education of a farmer is equivalent, on the average, to $6000 worth of 5 per cent bonds."[1]

133. Summary of some of the methods employed for increasing crop production. — The farmers of the future, therefore, to be successful must have special training. They must be able to carry on selection and breeding experiments, or at least know how to take advantage of these experiments in the choice of their seeds; they should know the principles involved in thorough cultivation and in the application of manures and fertilizers; they should determine by experiment the type of crop best adapted to the soil of their farms, and should by proper rotation of crops (that is, by sowing clover or other nitrogen-fixing plants, **150**, one year and corn the next) increase the fertility of their soil. If a farmer is a fruit grower, he should know how to prune properly, and he

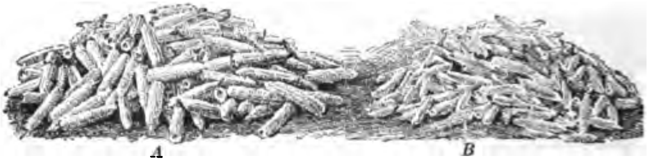

FIG. 59. — *A*, pile of corn resulting from cross-pollination; *B*, pile of corn resulting from self-pollination. — (Bailey.)

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[1] An Agricultural Survey of the Townships of Ithaca, Dryden, Danby, and Lansing, published by Cornell University, 1911.

should practice grafting to develop better types of fruits. If he has soil adapted for woodland, he should plant forest trees, and put into effect the principles of forestry. In fact, there are countless ways in which the farmer of the future can increase the yield of his acres if he but mixes brains with the labor of his hands.

CHAPTER IX

PLANTS IN THEIR RELATION TO HUMAN WELFARE

134. Introduction. — Thus far in our study of plant biology we have considered the principal functions carried on by plants and have observed some of the adaptations of structure for performing these functions. We have proved, for example, that plants must feed, digest, breathe, and carry

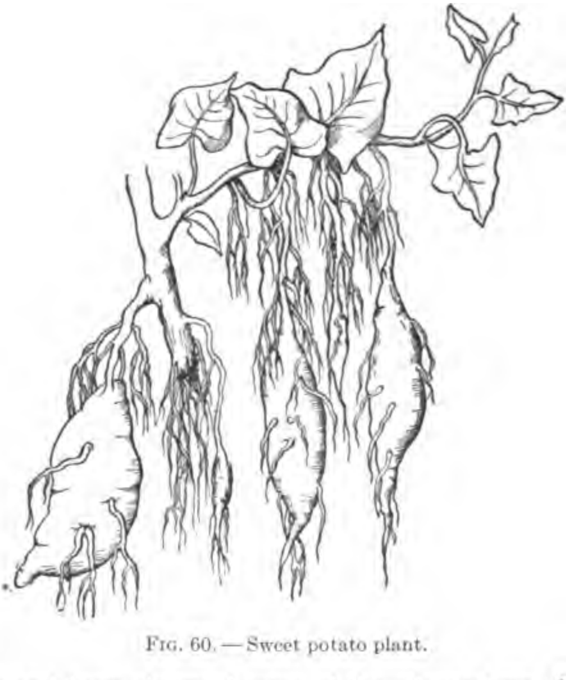

FIG. 60. — Sweet potato plant.

on oxidation in order to live and grow, and must reproduce their kind in order to perpetuate the species. We turn now to a discussion of some of the uses of plants to man, and some of the ways in which they are injurious.

I. Some of the Uses of Plants to Man

135. Uses of plants for food. — By repeated experiments we have proved that various parts of plants contain generous stores of starch, sugar, protein, and mineral matters. In our study of human biology we shall find that the foods which are essential for our bodies are composed of these same substances. It is for this reason that man and other animals are so largely dependent upon plants for food. As examples we may mention roots like parsnips, beets, and sweet potatoes; stems, like common potatoes, asparagus, and sugar cane; leaves, such as cabbage and lettuce; flowers, for example, cauliflower;

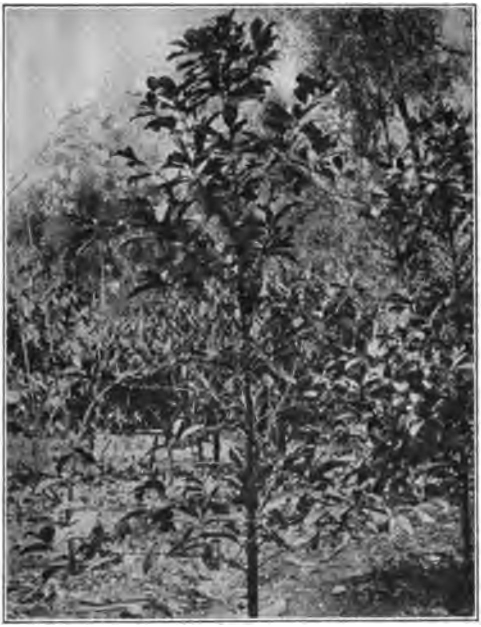

Fig. 61. — Coffee tree. Notice coffee berries along sides of branches. — (Courtesy of New York Botanical Garden.)

fruits, like apples and peaches; and seeds and grains, like beans, wheat, and corn.

136. Suggestions for further study of plants used as food. — Study No. 58. (Optional.) Visit a vegetable market, make a list of the various plant products sold for food, and arrange them in a table as follows:

Name of Food	Part of Plant Eaten					
	Root	Stem	Leaf	Flower	Fruit	Seed
String beans					X	X

Select one or more of the following topics for special study: wheat, corn, potatoes, oats, rice. Consult Bailey's "Cyclopedia of American Agriculture," Vol. II, "Crops," any encyclopedia, or the publications of the U.S. Department of Agriculture. Determine (1) the parts of the United States (or of the world) in which the crop is raised in large quantity, (2) the amount and value of a year's crop, (3) methods of harvesting and preparing the crop for the market.

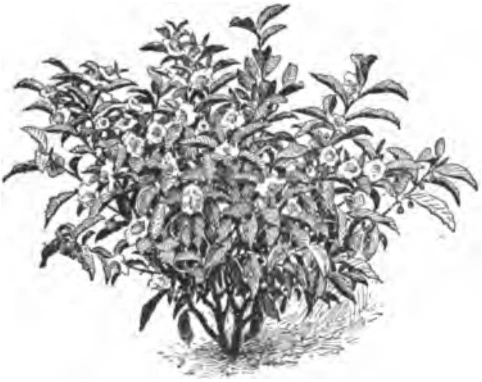

Fig. 62. — Tea plant. — (Bailey.)

137. Uses of plants for flavoring extracts, beverages, and medicines. — We saw in a previous section that many parts of plants are available for use as food by man. Because, also, of the presence of various flavoring compounds in plants, the following products are valuable. For instance, vanilla extract is made from the vanilla bean, pepper from pepper berries, horse-radish from the root of the horse-radish plant, and ginger from an underground stem.

We are dependent, too, upon plants for many beverages. The coffee berry supplies us with coffee, tea leaves with tea, and from the pods and seeds of the cocoa tree we obtain cocoa and chocolate. Grapes are used to make wines, from apples cider is prepared, and from grains of various kinds other alcoholic liquors are produced.

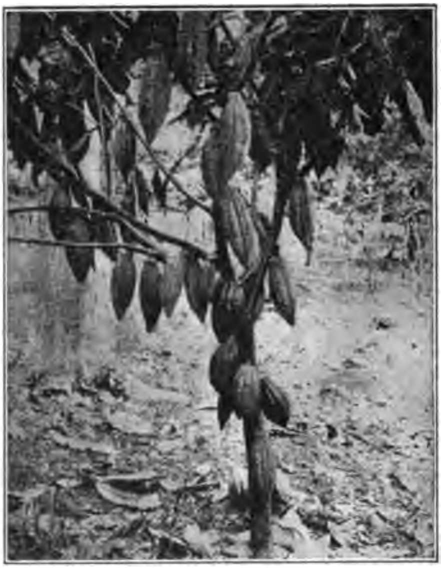

FIG. 63. — Chocolate tree. — (Courtesy of New York Botanical Garden.)

Quinine, the well-known remedy for malaria, was formerly obtained from the bark of a tree known as cinchona, which grows in Peru. This medicine is now obtained almost exclusively from trees cultivated in India and other Eastern countries. The camphor tree furnishes camphor gum; from the juice of poppy fruits opium and morphine are obtained; whole plants like peppermint supply us with valuable medicines. In fact, enormous numbers of drugs are prepared from various parts of plants.

138. Suggestions for further study of parts of plants used as drugs. — Study No. 59. (Optional.)

Visit a drug store or consult an encyclopedia, *e.g.* Bailey's "Cyclopedia of American Agriculture," Vol. II, "Crops," and make a list of common drugs obtained from plants. Fill out in your note-book a table like the following:

NAME OF DRUG	PART OF PLANT FROM WHICH IT IS OBTAINED					
	Root	Stem	Leaf	Flower	Fruit	Seed
Catnip . .		X	X			

139. Uses of plants for clothing. — (Quoted from Bailey's "Cyclopedia of American Agriculture," Vol. II, "Crops.") "Fiber-producing plants are second only to food plants in agricultural importance. In continental United States, however, cotton, hemp, and flax are the only fiber plants cultivated commercially; and aside from cotton and hemp, most of the raw fibers used in our industries are imported."

"The cotton of commerce is the hair or fiber on seeds of plants belonging to the Mallow family. . . . The plants are mostly shrubby, more or less branching, and two to ten feet high. . . . The fruit consists of three- to five-celled 'bolls,' which open at maturity through the middle of the cells, each cell liberating seven to ten seeds covered with long fibers. The fiber is a tubular hair-like cell, $\frac{1}{1500}$ to $\frac{1}{1200}$ of an inch in diameter, somewhat flattened and spirally twisted. It is this latter characteristic which gives the cotton its spinning qualities. . . .

"Picking or gathering cotton in the fields is a heavy item of expense. It must be picked by hand, as no mechanical appliance for harvesting has yet been invented which gives satisfactory results in practical working. The amount of cotton that one person can pick in one day varies from one hundred to five hundred pounds,

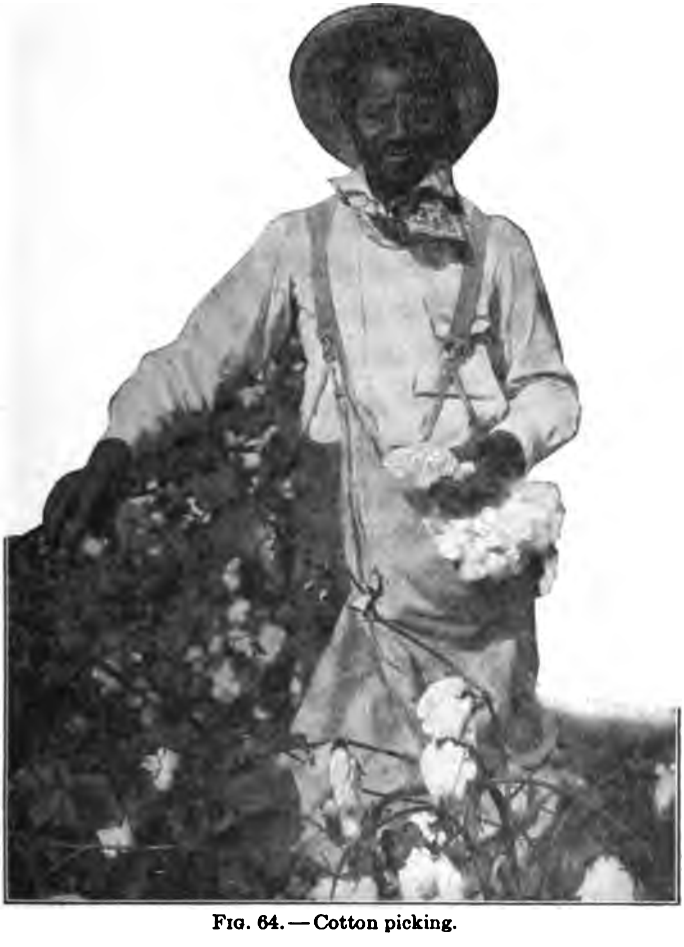

Fig. 64. — Cotton picking.

depending on the skill of the picker. One man can very easily care for the cultivation of twenty acres of cotton, but it requires two to four pickers to harvest such a crop rapidly enough to prevent loss. This extra labor in harvest time is usually supplied by the wives and children of the laborers. The harvest season extends over a period of about four months, beginning August 15 to September 10, according to locality.

"Cotton is probably a native of the tropical and semi-tropical regions of both hemispheres. The earliest records of the Asiatics and Egyptians speak of it; Columbus found it growing abundantly in the West Indies, while other early explorers found it growing in Mexico and South America. . . . There is no region in the world which has such a favorable combination of suitable land, intelligent and plentiful labor, cheap capital and adequate transportation facilities for the cultivation of cotton as the cotton belt of the United States. It has been the chief source of supply of the cotton mills of the world, for in this section has been raised several times the quantity of cotton produced in all other countries of the globe. There are various other countries which seem to possess the soil and climatic requirements for its growth, but for various economic reasons the industry has not been greatly developed in them; however, a considerable quantity is produced in the following countries in the order named: India, Egypt, China, Italy, Turkey, Brazil, West Indies, Mexico, South America, Australia, and the South Sea Islands."

140. Further study of fiber-producing plants. — Study No. 60. (Optional.) Select one or more of the following fiber-producing plants for further study: flax, hemp, jute, raffia, hat-straw. Consult Bailey's "Cyclopedia of American Agriculture," Vol. II, "Crops," or any encyclopedia. Determine (1) the parts of the United States (or of the world) in which the crop is raised in large quantity, (2) the amount and value of a year's crop, (3) methods of harvesting and preparing the crop for market.

II. THE USES OF FORESTS AND FOREST CONSERVATION

141. Uses of forests for fuel, lumber, and other commercial purposes. — In the earlier days of our country's history all the fuel for heating, for running locomotives and other engines was supplied from the forests. About one hundred and fifty years ago, coal was discovered in Pennsylvania, and one would suppose that since that time our forests would have been drawn upon less heavily for fuel. But it is estimated that the United States burns annually at the present time one hundred million cords of wood. While we are considering the uses of plants as fuel, we should remember that our enormous coal beds were without doubt formed from great tree ferns and other plants which lived in bygone ages. Petroleum, too, from which our kerosene oil is produced, is believed to be a product of plant decomposition.

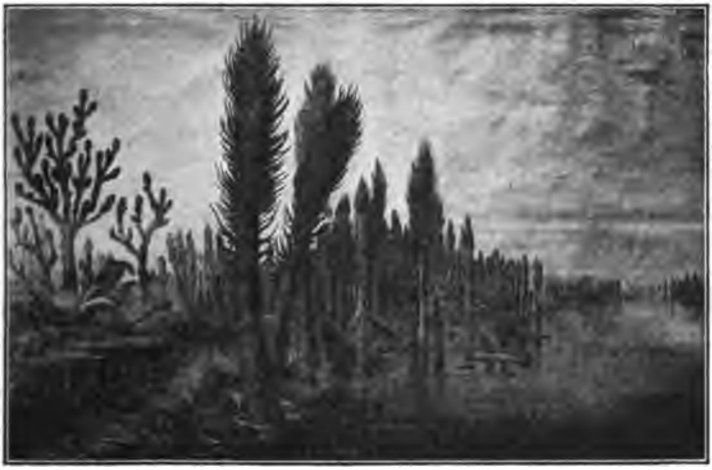

FIG. 65.—A view showing how the forests of the Coal Period probably looked.—(Tarr and McMurry.)

One has but to call to mind the enormous use of trees for framing and finishing houses, for furniture, for railroad ties, telephone and telegraph poles, for shipbuilding, and for boxes, barrels, and paper manufacture, to realize how seemingly indispensable are forests. When the early settlers reached this country, they found a virgin forest covering the whole land. Their first work was to clear land in order to get open spaces for cultivation and as a means of protection from attacks of the Indians. They cut down the trees ruthlessly and the timber and wood which was not needed was left to decay or become the prey of forest fires. This forest destruction has continued even to our own day. But at last men are beginning to see that unless this slaughter of our trees is stopped, our timber supply will soon be gone. In fact, government experts tell us that if the tree areas that yet remain are not managed according to a different system, *twenty years hence we shall reach the end of the timber supply in the United States.*

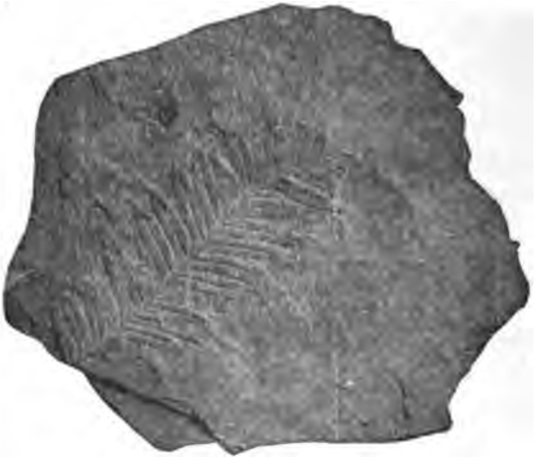

FIG. 66. — Rock containing a fossil fern which grew in the swamps of the Coal Period. — (Tarr and McMurry.)

142. Further study of forest products. — Study No. 61. (Optional.) Select one or more of the following forest products for fur-

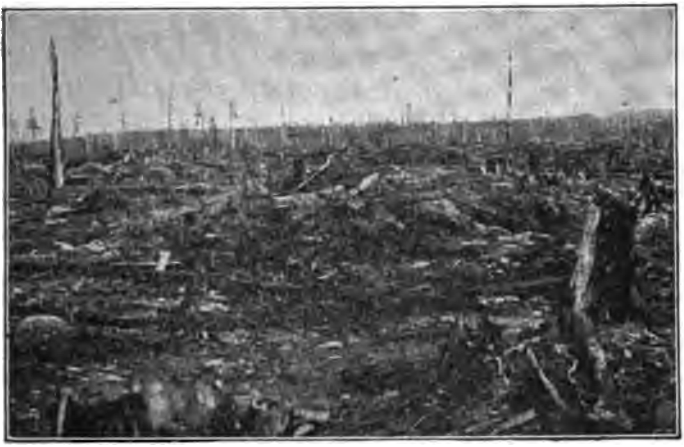

Fig. 67. — Wrong methods of lumbering. — (Warren.)

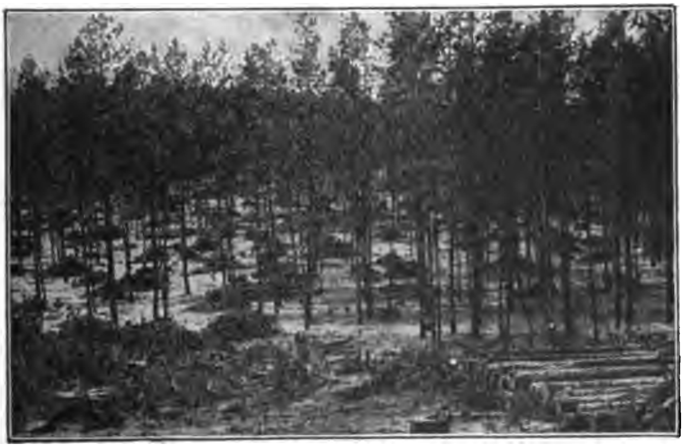

Fig. 68. — Right method of lumbering. Notice carefully piled logs, wood and brush, and uninjured young trees.

ther study: maple sugar, rubber, tar, turpentine, wood pulp, alcohol, charcoal. Consult Bailey's "Cyclopedia of American Agriculture," Vol. II, "Crops," or any encyclopedia. Determine (1) the parts of the United States (or of the world) in which the product is obtained in large quantity, (2) the amount and value of a year's crop, (3) methods of preparing the product for market.

143. Uses of forests in regulating rainfall and flow of streams. — We turn now from a consideration of our forests as a source of lumber and manufactured products to a discussion of their effect on the fall of rain and the flow of streams. It is probably true, in the first place, that the destruction of large tracts of forest lands means a lessened rainfall, at least so far as local showers are concerned. We saw in our study of the functions of the nutritive organs of a plant that great quantities of water are absorbed by the roots, carried up through the woody bundles of the stem, and given off through the stomata of leaves. It has been estimated that a single oak tree of average size gives off in a single season over one hundred and twenty-five tons of water. If we were to multiply this amount by the number of trees in a forest, we would get some idea of the enormous amount of water lifted into the air by this agency.

Not only do trees help to produce rain; they also conserve the rain when it falls by holding it in the soil, and preventing disastrous floods. Let us see how this is brought about. When the raindrops fall upon the tree tops, the water drips from leaf to leaf, and finally reaches the ground. Here it trickles down through the floor of the forest, which is formed of thick layers of decaying leaves, interlacing roots, and earth particles (see frontispiece). All these form a porous sponge which absorbs and holds back the water. Suppose, now, the trees are removed from the hillsides. When the rains come, there is no means of absorbing the water; instead, it flows rapidly over the surface, swelling the streams into torrents, which bring destruction and death as they flood the valleys and fields along their course. As the water flows over the surface of the land from which the trees have been cut, it carries along the richest part of the soil, thus causing loss of fertility in the uplands. The material thus carried away fills up the river beds and harbor mouths, and in many cases a heavy expense is entailed in its removal.

144. Dangers to forests. — We have already called attention to the threatened destruction of our American forests by careless lumbering. (See 141.) This means not only the wholesale cutting of large areas of trees, but the lack of forethought which lumbermen show in leaving dead tree trunks and branches to become the prey of destructive forest fires, which, when once started, devastate wide areas. The annual loss of property from this cause is conservatively estimated at more than one hundred million dollars.

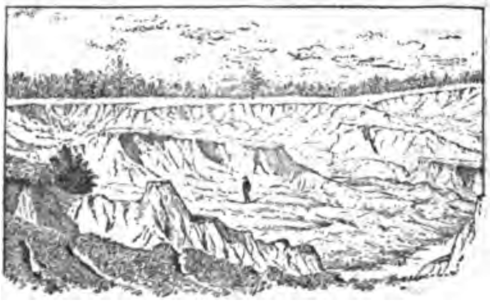
FIG. 69. — Excessive erosion of land caused by destruction of forests. — (Bailey.)

This forest débris of dead tree trunks and branches also furnishes breeding places for insects, which, when hatched, prey upon healthy trees. Another source of danger, especially to young forest growth, comes from permitting large flocks of grazing animals like cattle and sheep to feed upon and trample down the small trees. If we are to preserve the remnants of our once vast forest resources, a public sentiment must be thoroughly aroused which will compel the passage and enforcement of conservation laws.

145. Necessity for reforesting and for forest protection. — Surely, enough has been said to show the necessity for forest protection. Fortunately, laws are now being passed that will enable the National and some of the State governments to acquire large tracts of land for forest reservations. In many States these forest areas will protect the sources of large streams. There is great need of trained experts who will go through the forests, mark the trees which are mature enough to be cut, and decide which way they should fall to do the least damage to the younger growth. Again, large areas now devastated should be replanted with young forest trees, and this is also being done to a considerable extent. In many

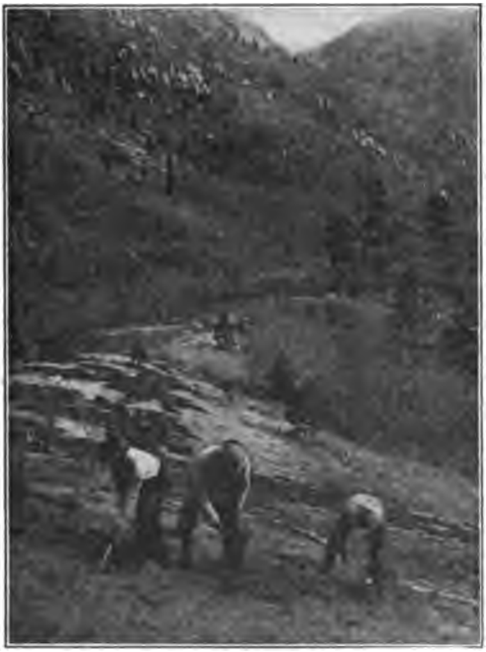

FIG. 70. — Planting young trees on hillsides.

foreign countries, notably in Germany, the forests are so used that year after year they supply the requisite timber, and still continue to do their much needed work in conserving the rainfall. Such must be the policy in our country if we wish to escape most disastrous penalties that always result from forest destruction.

Another method of forest protection is that afforded by cutting trees in such a way as to form long, treeless strips of land known as *fire lanes*. Systems of telegraphic communication from one part of the forest reserves to another and *fire wardens* are necessary factors in efficient protection of forests.

III. FUNGI AND THEIR RELATION TO HUMAN WELFARE

146. Fungi. — Thus far we have confined our attention to plants which are easily visible to the naked eye and which consist of roots, stems, and leaves. While we ordinarily think of these as the common plants, in reality the most common plant organisms are those which have neither roots, stems, nor leaves, and which in many cases are microscopic in size. The smallest and most numerous of these are known as *bacteria*, which are found all about us, in the soil, in the air we breathe, on the food we eat, and in the water we drink. Bacteria belong to a great group of plants called *fungi*. All fungi are characterized by the absence of chlorophyll, hence plants of this group cannot manufacture their carbohydrate food out of materials from the soil and air, but are dependent on foods made by green plants. More familiar to us, perhaps, than bacteria are the fungi known as mushrooms and toadstools, and the molds and mildews. Still other fungi are the yeasts, the rusts, and the smuts. Because of the enormous economic importance of many of these forms, we shall consider more or less in detail the structure, functions, and life-history of several of them.

A. Bacteria[1]

147. Microscopical appearance and size of bacteria. — Every one is familiar with the fact that if a bouquet of flowers is left for some time in a vase of water, the stems decay and disagreeable odors are given off. This is a common example of the action of bacteria, for all decay is due to the work of these organisms. When we come to examine the flower-stems or the putrid water, we find a slimy scum. If we put a drop of this scum on a slide, cover with a cover-glass, and examine with the highest powers of the microscope, usually we would see many different forms of living things. Some of them would probably appear relatively large, and these, as we shall see later (Chapter IV, "Animal Biology"), are single-celled animals. A closer examination will disclose countless numbers of very minute, colorless organisms; these are the bacteria. A careful study of many kinds of bacteria shows that they have several characteristic shapes (see Fig. 71) by means of which they can be roughly classified. Some are rod-shaped (like a firecracker), some are spherical, or egg-shaped, and still others are spiral-shaped. *Each bacterium is a tiny bit of translucent protoplasm, inclosed in a cell wall of cellulose.* Thus far no nucleus has been discovered in any kind of bacteria. Because of their cellulose walls, and because of their likeness to certain low forms of green plants, biologists now regard these organisms as plants rather than animals.

Some of the rod-shaped bacteria have one or more long, hairlike projections from the ends, called *cil'i-a*, which give the germs still further resemblance to firecrackers. These cilia lash about rapidly, and thus drive the cells through the water. The spiral bacteria roll over and over, and advance in a spiral path like a corkscrew. Other forms have rapid movements, but it is not known how they are accomplished.

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[1] Because of the importance of bacteria in relation to sanitation, it may be found advisable to consider this whole topic in connection with human biology. Sections **148–154** will therefore be repeated in the book on human biology.

It is very difficult to get any clear notion of the extreme minuteness of bacteria. It means but little to say that the rod-shaped forms are $\frac{1}{5000}$ of an inch in length. The imagination may be somewhat assisted if we remember that fifteen hundred of them arranged in a procession end to end would scarcely equal the diameter of a pin head.

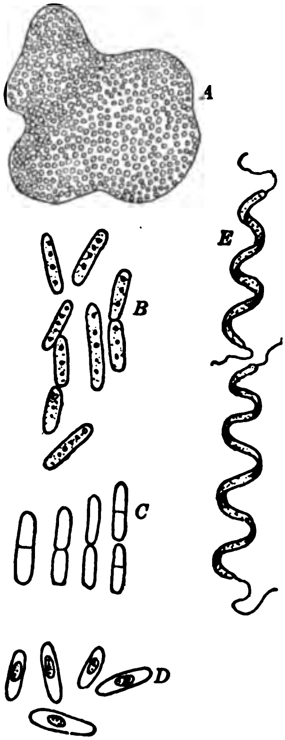

FIG. 71. — Various forms of bacteria.

A, a colony of spherical bacteria (*coccus*, plur. *cocci*); *B*, rod-shaped bacteria (*bacillus*, plur. *bacilli*); *C*, rod-shaped bacteria dividing; *D*, rod-shaped bacteria, each containing a spore; *E*, spiral bacteria (*spirillum*, plur. *spirilla*) each with cilia.

148. Reproduction of bacteria. — When conditions are favorable, the production of new cells goes on with marvelous rapidity. The process is something as follows: The tiny cells take in through the cell wall some of the food materials that are about them, change this food into protoplasm, and thus increase somewhat in size. The limit is soon reached, however, and the bacterium begins to divide crosswise into halves. The mother cell thus forms two daughter cells by making a cross partition (cell wall of cellulose) between the two parts. (See Fig. 71, *C*.) If the daughter cells cling together, a chain or a mass is formed. Oftentimes they separate entirely from each other. In either case the whole mass of bacteria is called a *colony*.

It usually takes about an hour for the division to take place. Suppose, then, we start at ten o'clock some morning with a single healthy bacterium. If conditions are favorable, there would be two cells at eleven o'clock, and by twelve o'clock each of these two daughter cells would form two granddaughter cells; the colony would then number four individuals. Should this process continue for twenty-four hours, or until ten o'clock on the day after the single bacterium began its race, the colony would number 16,777,216 bacteria. "It has been calculated by an eminent biologist," says Dr. Prudden,[1] "that if the proper conditions could be maintained, a rodlike bacterium, which would measure about a thousandth of an inch in length, multiplying in this way, would in less than five days make a mass which would completely fill as much space as is occupied by all the oceans on the earth's surface, supposing them to have an average depth of one mile."

149. Necessary conditions for the growth of bacteria. — Such startling possibilities as those suggested in the preceding section fortunately can never become realities, for the favorable conditions to which we have referred soon cease to exist. *Bacteria, like all other living organisms, require food, oxygen, moisture, and a certain degree of warmth.* Let any one of these conditions be withheld, and the cells either die or cease to be active. Sometimes, when food or moisture begins to fail, the protoplasm within each cell rolls itself into a ball and covers itself with a much thickened wall. This protects it until it again meets with conditions favorable for growth. The process we have been describing is known as

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[1] "The Story of the Bacteria," by Dr. T. Mitchell Prudden. G. P. Putnam's Sons, New York.

spore formation; the tiny *protoplasmic* sphere is called a *spore,* and its dense covering a *spore wall.* (Fig. 71, *D.*) In this condition bacteria may be blown hither and yon as a part of the dust. They may be heated even above the temperature of boiling water without being killed. When at length they settle down on a moist surface that will supply them with food, the spores burst their thick envelope, assume once more their rod-shaped or spiral form, and go on feeding, assimilating, and reproducing their kind.

150. Relation of bacteria to soil fertility.—Having discussed somewhat the structure and functions of bacteria, we are now to consider the great importance of these microscopic organisms to human welfare. In the first place, were it not for their never ending activity, all life upon the earth would soon cease to exist. Let us see why this is so. When animals or plants die, their bodies fall upon the ground, and were these lifeless masses not taken care of, the whole surface of the earth would long since have been covered with a vast number of unburied organisms. All this dead material, however, as we have seen, is food for the countless bacteria; they cause it to decay, and thus decompose it into simpler chemical compounds that can soak into the earth and then be used in the nu-

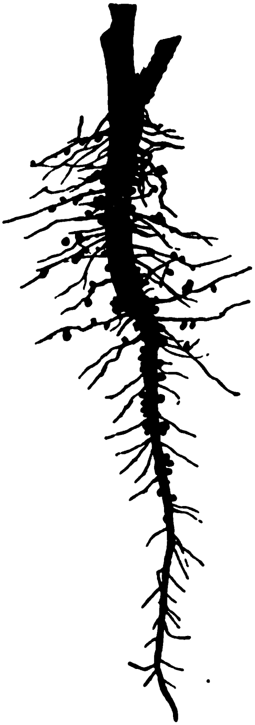
Fig. 72.—Roots of horse bean, showing numerous root-tubercles.—(Strasburger.)

trition of the higher plants. And since plants are constantly taking from the soil the food materials which they need, this soil would tend to become less and less fertile were it not for the work of the bacteria that caused decomposition. This is the reason why rotting manure adds to the fertility of soil.

Again it has been proved that certain kinds of bacteria directly increase the amount of nitrogen compounds that are so essential for plant growth. It has long been known that corn and other crops will grow better in soil that has just borne a crop of peas, beans, clover, or other members of the pea family. Within recent years an explanation of this fact has been found. When the roots of those pod-bearing plants are examined, small swellings are seen. These contain multitudes of bacteria that are able to take the free nitrogen from the air, where it exists in such abundance, and store it away in the form of nitrates which are very important mineral matters needed by all crops. Since those bacteria can be put into soils that do not have them, it may be possible in the near future to restore much of the fertility which has been lost.

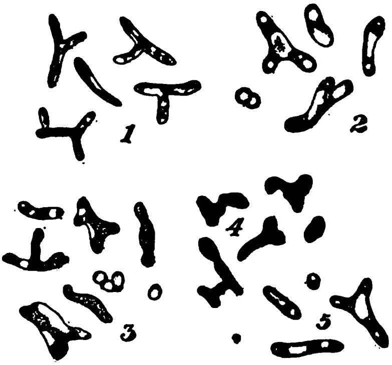

FIG. 73. — Bacteria from root-tubercles. — (Duggar.)

151. Relation of bacteria to the flavors of food. — Again, many of the flavors of food are due to the action of bacteria. Meats, for instance, when freshly killed, are tough and tasteless. If allowed to stand, however, by the decomposing action of bacteria these meats become tender and acquire their distinctive flavors. A similar action takes place when butter or cheese ripens, and the dairy industry has been perfected to such a degree that bacteria of certain kinds have been proved to give rise to definite flavors, and these bacteria can be produced in pure cultures for the dairymen.

152. **Bacteria in the industries.** — Without the help of bacteria the preparation of linen, jute, and hemp would be impossible. All these valuable products are plant fibers which are connected with woody materials so closely that they cannot be separated without first subjecting the stems of flax, hemp, and jute to a process of decay in large tanks of water. Moisture and warmth induce the rapid growth of germs, and this process loosens the tough fibers so they can be separated from the useless parts of the plant.

The change of alcohol into vinegar is caused by bacteria. Likewise in the preparation of indigo other forms of bacteria are all important.

153. **Bacteria as the foes of man.** — Unfortunately, however, there are certain germs that find favorable conditions for growth only in living animal tissue. Thus the bacterium of consumption grows in the lungs, the germ of diphtheria in the throat, and the bacteria that cause typhoid fever in the intestines. These disease-producing germs are called by Dr. Prudden "man's invisible foes." Yet wonderful progress is being made in the fight against them. We have learned how to check the ravages of cholera, typhoid, and diphtheria, and even consumption is found to be a preventable disease. Further discussion of bacteria will be found in several of the subsequent chapters.[1]

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[1] For laboratory work on bacteria, see Chapter II, "Human Biology." Also consult Peabody's "Laboratory Exercises in Anatomy and Physiology" (1902), pp. 100–107.

B. Yeast (Optional)

154. Microscopical appearance and size of yeast. — A small piece of a cake of compressed yeast, mixed in a spoonful of water, forms a milky fluid that is much like so-called bakers' or brewers' yeast. If we examine with the microscope a bit of this mixture in the same way in which the bacteria were studied, we find that it consists of innumerable bodies of minute size. These are *yeast cells*. Each cell is more or less egg-shaped, and is composed of colorless protoplasm inclosed within a wall of cellulose. By the use of special stains, a nucleus becomes visible. (The spherical dots seen in fresh yeast cells are known as *vacuoles* and are filled with a colorless liquid.) *Yeast, like bacteria, is regarded as one of the lowest forms of plant life.*

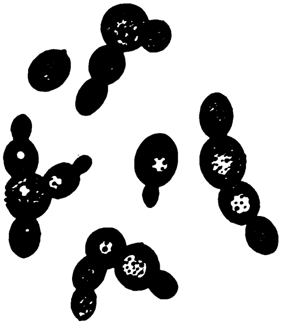

Fig. 74. — Yeast cells, showing method of reproduction by budding. Nuclei are not shown. Clear spaces are vacuoles.

155. Reproduction of yeast. — Most of the cells that we are looking at are not separate individuals, but are strung together in little chains. This fact leads us to a discussion of the method of reproduction of yeast. When there is a sufficient supply of food, moisture, and oxygen, and when the temperature is favorable, these living plant cells begin to feed and to grow. They soon reach their full size, and then the cell wall is pushed out at the side by the growing protoplasm. In this way a *bud* is formed. This continues to grow and soon becomes a daughter cell, closed off from the mother cell by a wall of cellulose. Meanwhile, one or more buds may be forming on the outside of the daughter cells. If all these cells cling together, a colony is formed which consists of a mother cell (largest in size), one or more daughter cells, and several tiny granddaughter cells. The individual cells are easily separated from one another. This method of reproduction is known as *budding* (Fig. 74).

156. Changes caused by yeast. — A yeast mixture may be easily prepared for experimentation by pouring into a jar a cup of water, adding a spoonful of molasses, and a spoonful of the milky fluid made as described in 154.

If the jar with its contents is set aside in a warm place (70° to 90° F.) for a short time, it begins to "work," and bubbles of gas rise to the surface. At the end of several hours, we notice that the sweetness of the molasses is disappearing, that the mixture begins to smell sour, and that a sharp, biting taste is becoming evident. All these changes are caused by the growth of living yeast cells.

Now, what is the gas that is formed in this process, and what causes the changes in taste and odor? To answer these questions we must carry our experiments still further. When the mixture is "working" well, the bottle should be tightly closed with a rubber stopper, through which extends one arm of an inverted U-shaped tube. The other end of this tube should run over to the bottom of a test tube half-filled with limewater. The gas that has been rising through the yeast mixture now passes through the U-tube, and as it comes in contact with the limewater, the latter changes to a milky-white color. This proves that the gas formed during the growth of yeast is *carbon dioxid*.

After "working" a day or two, the yeast mixture will have a strong taste and odor. A part of it should then be poured into a glass Florence flask (commonly used in the chemical laboratory for boiling liquids), and the mouth should be closed by a rubber stopper. The short arm of a long delivery tube should be passed through this stopper. When the flask is heated gently, some of the liquid is changed to a vapor. If the delivery tube is cooled by covering it with cloths wet in cold water, the vapor condenses into a liquid, which comes from the end of the tube in drops. This operation we have been describing is known as *dis-til-la'tion*. *In distilling a liquid, we first convert it into a vapor, and then condense this vapor into a liquid.* After collecting a few spoonfuls, the liquid should be slowly distilled a second time. Then we obtain a colorless fluid that has the distinct smell and taste of *alcohol*. It burns, too, with a pale blue flame. And so we learn that *yeast, as it grows in the molasses mixture, changes the sweet substances into carbon dioxid and alcohol, a process that is known as alcoholic fer-men-ta'tion.*

157. Uses of yeast. — When bread is made, water (or milk), butter, salt, sugar, and yeast are added to flour. After the mixture has been stirred together, a sticky mass of dough is formed, which in a warm place begins to rise. This is due to the fact that the yeast cells change the sugar into alcohol and carbon dioxid. Bubbles of gas are thus imprisoned in the sticky dough. While expanding and seeking to escape, they make the solid mass porous. After the bread has risen sufficiently, it is kneaded in order to break up the large bubbles and in order to distribute the gas throughout the dough. When the bread is baked, the alcohol and carbon dioxid pass off into the air, leaving the bread light and digestible. These minute organisms are also of great commercial importance in the manufacture of alcohol and of all kinds of liquors. It is known that yeast cells are found commonly in the air. As different kinds of fruits ripen, they are usually more or less covered with yeast or its spores. When, therefore, grapes are gathered and their juice is pressed out, the sweet liquid is soon alive with the busy cells, and fermentation begins at once. In this way wines are produced. Cider is produced by the fermentation of apple juice.

In the manufacture of beer and of other malt liquors, barley is commonly used. The grain is soaked and allowed to sprout for a short time, until the starch is changed to grape sugar. The barley kernels are then killed by heat to prevent further changes, and the grain is then known as *malt*. When this is put into water, the sugar is extracted. Yeast is then added, and the mass ferments. The beer thus formed contains 2 to 5 per cent of alcohol.

Distilled liquors, or spirits, are obtained from wines and other fermented liquors by the process of distillation, the principles of which have already been explained. Brandy is made by distilling wine, whisky is obtained from fermented corn and rye, and rum is manufactured from molasses. All of these liquors contain a large percentage of alcohol (40 to 50 per cent).

158. Suggestions for laboratory work on yeast. — No. 62. Students should examine the appearance of yeast cells under the low and high powers of the compound microscope. If time permits, the demonstration of carbon dioxid production and of distillation of alcohol might well be made. (See Peabody's "Laboratory Exercises," pp. 94–99, Henry Holt & Co., New York City.)

C. Bread Mold (Optional)

159. Structure of bread mold. — If pieces of bread or cake be moistened, and placed in a dish, and covered with a bell-jar in the dark, in a few days grayish patches will appear in places on the surface of the bread. This growth is due to the activity of one of the fungi, known as a *mold*, and will probably be the kind called bread mold. No care is required to produce the plant in quantities; on the contrary, as common experience shows, some pains must be taken by the housekeeper to prevent it from spoiling food.

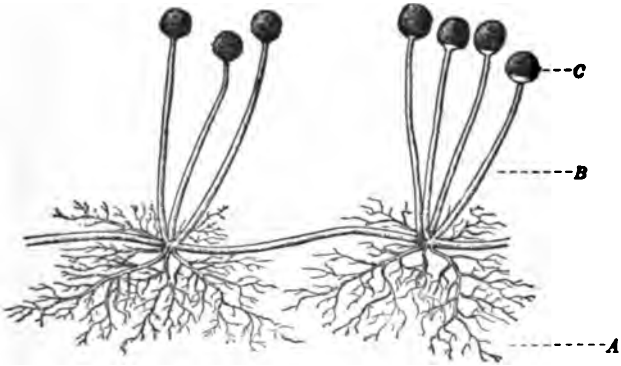

FIG. 75. — Bread mold, showing nutritive hyphæ (*A*); reproductive hyphæ (*B*); and spore cases (*C*). — (Osterhout.)

When the bread mold is examined with a hand lens, it is seen to consist of a mass of fine interlacing threads called the *mycelium.* (See Fig. 75.) Single threads are known as *hyphæ.*

160. Reproduction and life history of bread mold. — Some of the hyphæ in their growth assume an upright position, and each of these at the upper end develops a little globular white mass or *spore case.* (See Fig. 75.) An examination with the high power of the microscope shows that the spore cases are filled with tiny cells known as *spores.* When the spores are ripe, the spore cases appear brown or black, they break open, and the spores are scattered. If these spores fall on food of some kind, such as bread, they begin to germinate, and each one produces another mass of threads with spore cases on erect hyphæ. In other words, the mold produces spores and the spores reproduce the mold. The spores of molds are in the air nearly everywhere, hence we see why molds appear so quickly on foods of various kinds, provided they are moist and in a warm place.

161. Nutrition in the fungi. — Molds, like other fungi, as we have already said, cannot manufacture their own food out of the materials obtained from the soil and air, but are dependent on foods made by green plants. Certain of the threads called the *nutritive hyphæ* form ferments which digest the food compounds found in bread or other substances on which the mold is growing, and then the digested food is absorbed, used in growth, and in the production of energy. Other threads develop the spore cases and so are called *reproductive hyphæ.* Hence, it is evident that fungi, like all plants, carry on both nutritive and reproductive functions, but on account of the lack of chlorophyll are, like animals, dependent on the green plants for their supply of food.

162. Suggestions for laboratory work on bread mold. — No. 63. Sow bread mold as suggested in **159** in sufficient quantity to supply each two pupils with a piece of the moldy bread. Pupils should examine a specimen with a hand magnifier, describe the appearance of the mycelium and hyphæ bearing spores, and should then make a drawing to show these points. Some of the spore cases should be placed on a slide in water and covered with a cover glass. If the glass cover is tapped with a pencil, some of the spore cases will be ruptured. The preparation should then be examined with the high power of the compound microscope, and the ruptured spore cases drawn, together with a few of the escaping spores.

D. Other Fungi (Optional)

163. Mushrooms. — Mushrooms are forms of fungi which are often called "toadstools," especially if they are supposed to be poisonous. All fungi of this kind should, however, be called mushrooms, since their structure and life history are similar. The conspicuous part of the plant, the umbrella shaped structure so familiar to all, is really the reproductive organ of the plant, the part that bears the spores (Fig. 76). The nutritive organs are a mass of threads (as in the mold) which lie beneath the surface, where they absorb the foods from some decaying material in the soil to give rise to the reproductive body.

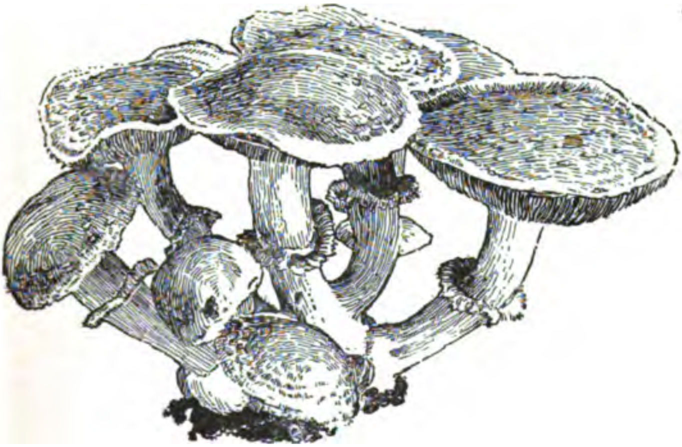

Fig. 76. — An edible mushroom.

As indicated above, many mushrooms are poisonous, but a few kinds are known to be edible.[1] Mushrooms are not especially nutritious; that is, they cannot take the place of the cereals and other staple foods, but they serve to add to the variety of materials which are more valuable for their flavoring qualities than for the quantity of nutriment they contain. Commercially the cultivated mushroom is of considerable importance, especially in Europe. Paris is said to be the center for the sale of this product. In the year 1901 it was estimated that 10,000,000 pounds of cultivated mushrooms passed through the markets of Paris. In this country the mushroom is of commercial importance only in the regions of the larger cities.

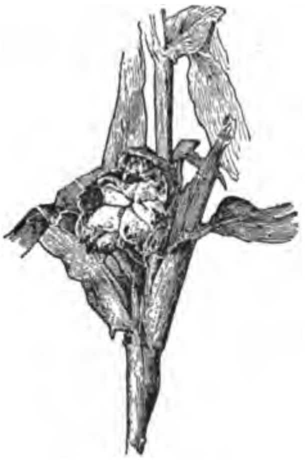

FIG. 77. — Corn smut on an ear of corn.

164. Rusts and smuts. — The fungi known as *rusts* receive their name from the rusty appearance in an early stage of their growth which they cause on the stems and leaves of plants which they attack. The cereals, wheat, oats, barley, and rye, are the crops which this fungus injures most. In the case of wheat, half of the crop or even more may be destroyed.

The very suggestive name of *smut* is given to another fungus which affects all the cereals named above, and corn as well. In the case of corn, this plant often affects the ears as well. The name is probably given on account of the appearance of the mass of black spores. If one touches these spores, especially those of corn smut, with the finger, and then rubs the finger on some white paper or cloth, a sooty mark is left. The damage done by smuts is very considerable. In case of the corn crop alone it has been estimated that a yearly loss of 20 per cent of the crop, or $20,000,000, is caused thereby, and in the other cereal crops the loss is even greater. It should be mentioned in closing this discussion that the rusts and smuts are only two of a large number of fungous diseases that affect plants.

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[1] So many deaths are caused by using poisonous instead of edible mushrooms that it is never safe to eat wild forms until they have been identified by an expert.

CHAPTER X

PLANT CLASSIFICATION

I. COMMON METHODS OF CLASSIFICATION

165. Herbs, shrubs, and trees. — One way of classifying the common plants with which we are most familiar is that of calling them either *herbs, shrubs,* or *trees.* This classification is based upon the general similarity in size, form, and texture of the plants which are assigned to each group. Thus when we think of a *tree* we have in mind a plant which, when

FIG. 78. — Base of one of the giant trees of California. — (Tarr and McMurry.)

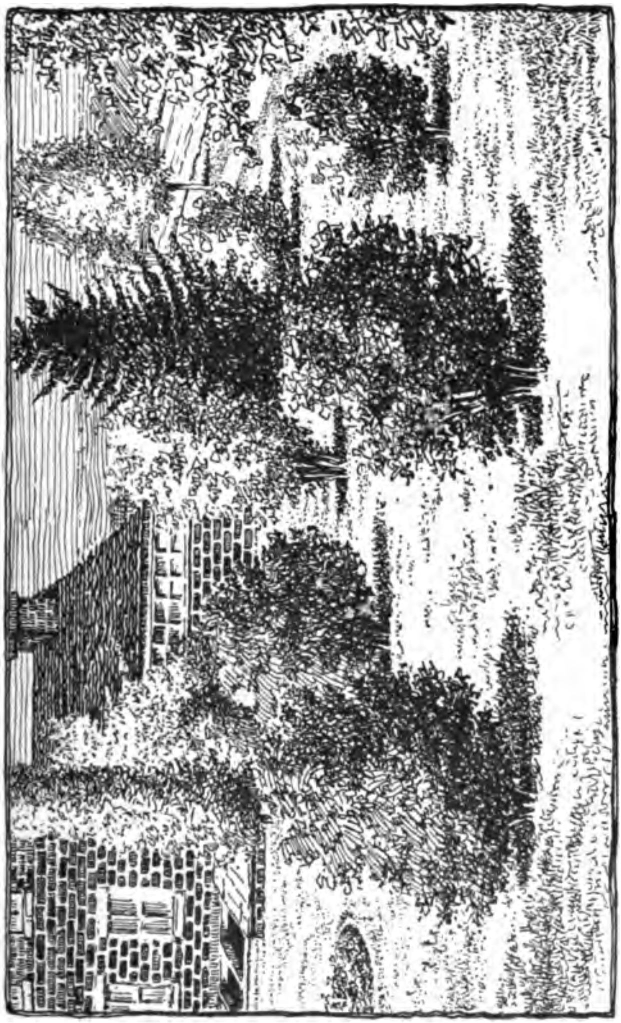


Fig. 79. — Trees and shrubs.

mature, is of large size, with a single woody trunk and branches. This trunk may extend up nearly to the top of the tree, as in the case of the pines and spruces, or some distance above the ground the trunk may divide into branches, as is true in the elms and maples.

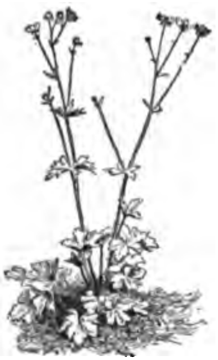


FIG. 80. — An herb.

A *shrub*, on the other hand, is usually of smaller size even when fully grown than is a tree; it commonly does not have a single trunk, but several woody stems which often start from the ground level, as in the lilac, rose, and witch hazel. Both shrubs and trees are alike in that their stems and branches do not die down to the ground at the end of the season.

An *herb*, as the term is used in plant biology, is a plant of relatively small size, with comparatively little woody material in its stem, which dies down to the ground level at the close of the season. Such are beans, corn, and morning glories. The roots or underground stems of some herbs — for example, dahlias, carrots, and parsnips — remain alive ready for growth the next year. These facts suggest another method of classifying plants, namely, as:

166. Annuals, biennials, and perennials. — When a plant attains its maturity in one season's growth and then dies, as do beans, corn, and morning glories, such a plant is called an *annual*. Many plants which have fleshy roots, like the beet, carrot, and parsnip, do not produce flowers and seeds until the second year. During the first season after the seed is planted the food manufactured in the leaves passes down the plant and is stored beneath the ground. At the end of the season the stems and leaves above ground die; but if this root remains in the ground or is planted the next season, stems, leaves, and flowers develop rapidly, and finally seeds are formed, the food stored up the preceding season being drawn upon for the development of these parts. Plants which have a life history like this and which live for two years only are

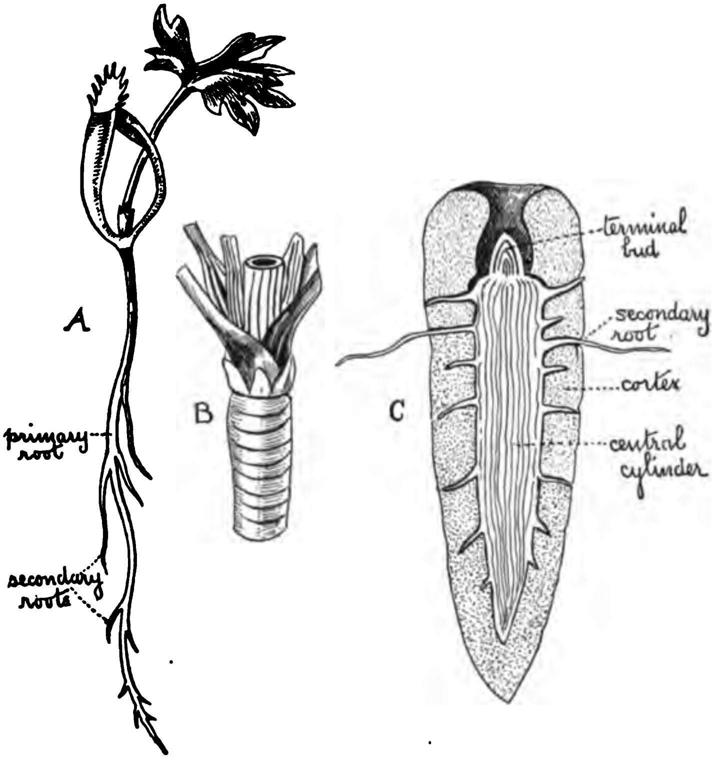


FIG. 81. — Carrot. *A*, young seedling; *B*, enlarging root early in season; *C*, section of enlarged root late in season.

called *biennials* (Latin, *bi* = two + *annus* = year). *Perennials* are plants that live year after year. Hollyhocks and dahlias, for instance, store food in fleshy roots year after year, while the parts above ground die, as in the case of beets and carrots. Other perennials, like trees and shrubs, lose only their leaves at the end of each season.

167. Deciduous and evergreen trees and shrubs. — Trees and shrubs may be classified as *evergreen* or *deciduous*. Since the leaves of pines, spruces, and hemlocks remain green and attached to the stem during the winter, these plants are known as *evergreens*. Certain shrubs (rhododendrons, arbutus, and wintergreen, for example) also keep their green leaves throughout the winter, and so in a sense they may be regarded as evergreens. Maples, elms, and horse-chestnuts, on the other hand, shed their leaves in autumn; they are therefore said to be *deciduous* (Latin, *de* = from + *cadere* = to fall).

168. Field work on plant classification. Optional. — No. 64. If possible, teachers should accompany their pupils on a field trip, point out and name the plants best adapted for a study in classification, using perhaps an outline like the following:

NAME OF PLANT	HERB	SHRUB	TREE	SIMPLE LEAVES	COMPOUND LEAVES	OPPOSITE LEAVES	ALTERNATE LEAVES	DECIDUOUS	EVERGREEN
Rose .		X			X		X	X	

II. SCIENTIFIC METHOD OF CLASSIFICATION

169. Scientific classification of plants. — The various methods of grouping plants that we have thus far considered do not indicate real relationships among plants, for these schemes call attention only to certain superficial resemblances and differences in form, or size, or habit. True scientific classification seeks to bring together into a given group all the plants that are closely related to each other; that is, those which are probably descended from common ancestors. In the first place, all plants are divided into two great groups known as *seed-producing plants*, and *spore-producing plants*. The first is the group to which most of our attention has thus far been given, and it embraces the herbs, shrubs, and trees with which we are most familiar. We should bear in mind, however, that many plants, like the palm and rubber plant, which do not produce flowers in our climate, develop flowers, fruits, and seeds when they are growing in their natural home. Other plants with inconspicuous flowers — for example, grasses, elms, and pines — also belong to this great group of seed-producing plants.

Sub-kingdom I, Seed-producing Plants (Optional)

170. Gymnosperms and angiosperms. — Seed-producing plants are still further subdivided into two groups. The first group includes all plants like the pines, hemlocks, and spruces, in which the seeds are not produced in ovaries, but at the base of scale-like leaves which are usually grouped together to form *cones;* hence the name cone-bearing plants, which will apply to the common forms. The whole group is known as *gymnosperms* (from Greek meaning naked seeds).

Plants like beans, cucumbers, and pansies, on the other hand, develop their seeds in ovaries, and these and all other plants of this type constitute the second of the two sub-divisions, which is known as the *angiosperms* (from Greek meaning having a vessel for seeds).

171. Monocotyledons and dicotyledons. — Again, the seed-producing plants may be classified according to the number of cotyledons found in the seed. The corn, gladiolus, and lilies, for example, have seeds with one cotyledon, and hence these are known as *monocotyledons* (Greek, *mono* = one + cotyledon). Beans, peas, and maples, on the other hand, have two cotyledons and are therefore called *dicotyledons* (Greek, *di* = two + cotyledons). There are other striking characteristics which distinguish these two groups of angiosperms, which have already been brought out in our laboratory work, as the following table will show:

	MONOCOTYLEDONS (Corn, tulip, gladiolus)	DICOTYLEDONS (Bean, horse-chestnut, pansy)
Number of cotyledons	one	two
Veining of leaves	parallel	netted
Stem structure	woody bundles scattered through pith	bark, wood in distinct annual rings, pith in center
Number of stamens and other parts of flower	based on plan of three or some multiple of three	based on plan of five or some number other than three

172. Plant families. — Continuing our classification of the angiosperm group still further, we find that the dicotyledons are subdivided into over one hundred and sixty so-called plant *families*, some of which are the violet family, the buttercup family, the rose family, and the pulse family. This grouping into families is based largely upon flower structure, and so it sometimes happens that an herb and a tree belong to the same family. For example, the pea, bean, and the locust tree all belong to the pulse family, since they have flowers closely resembling each other.

173. Plant genus. — Again, each of the 160 or more families is made up of a varying number of more closely related plant groups, each of which is known as a *genus*. The rose family, for example, has fourteen genera, some of which are the pear genus, the rose genus, and the cherry genus.

174. Plant species. — Once more, each genus consists of a varying number of *species*, the members of which resemble each other very closely. The pear genus consists of the pear species, the apple species, and the crab apple species. Species, again, may be still further subdivided into *varieties*, in which the plants are more closely related (*e.g.* Baldwin and Greening varieties among apples). And finally a species (or variety) is made up of *individual plants*, that resemble each other in all essential respects.

Sub-kingdom II, Spore-producing Plants (Optional)

A. Ferns

175. The fern plant. — We turn now from a discussion of seed-bearing plants to a consideration of those plants which never produce flowers or seeds. As a representative of the highest group of plants without seeds, we will study the ferns. The majority of ferns grow in damp, shady places, and among the common kinds we may name the brake, the maiden-hair, and the rock fern. In any one of these ferns the parts above ground which are true leaves are known as *fronds*. The main axis of each frond runs throughout the leaf, and to each side are attached the leaflets, which may or

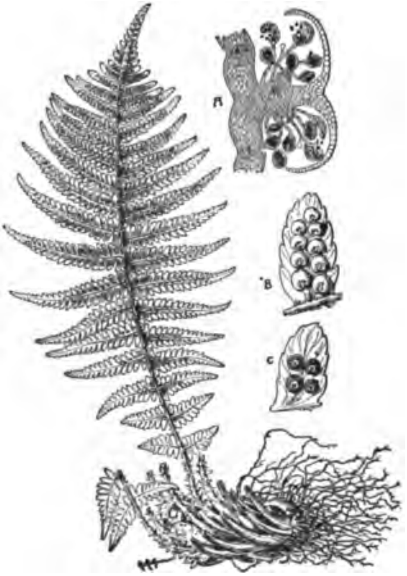


FIG. 82. — Fern plant (Aspidium), showing roots, rhizome, and frond: *A*, section of fruit dot (sorus), showing spore cases, some of which are ejecting their spores; *B*, portion of a leaflet, showing unripe fruit dots; *C*, portion of a leaflet, showing ripe fruit dots. — (Strasburger.)

may not be still further subdivided. Hence, a fern leaf is usually compound, and is strikingly graceful in its appearance.

Beneath the ground the fronds grow from a horizontal stem called the *rhizome*, which is more or less enlarged for food storage, depending on the kind of fern. To this rhizome are attached the roots by which the plant is supplied with soil-water. The fern plant, therefore, like seed-bearing plants, has all three kinds of nutritive organs (roots, stem, and leaves), and carries on carbohydrate manufacture in the green fronds, storing away the food in the rhizome, since the leaves die to the ground each year. The following spring the tiny leaves push up through the ground from the underground stem, unrolling and spreading their leaflets from the base to the tip.

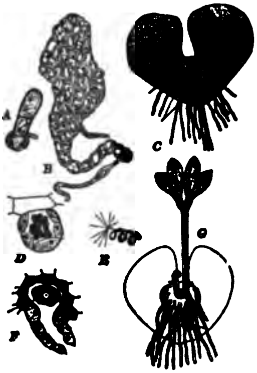


Fig. 83. — Development of fern plant.

A, a germinating fern spore; *B*, a later stage in germination; *C*, a full-grown prothallus, showing rhizoids, antheridia (or spermaries, and archegonia (or ovaries; *D*, section of antheridia (or spermary); *E*, a sperm cell; *F*, a section of archegonia (or ovary) containing an egg-cell; *G*, young fern plant developing from a fertilized egg-cell in an ovary, still attached to the heart-shaped prothallus. — (Parker.)

176. Fern spores. — On the under surface of some of the leaflets of the ferns named above are little dots which are often brown. These are known as fruit-dots (*sori*). Each fruit dot, if examined with a microscope, is found to consist of several smaller objects known as *spore-cases*. (*B*, *C*, Fig. 82.) When these tiny spore cases are ripe, they open, often with considerable force, and eject a powder, each particle of which is called a *spore*. (Fig. 82, *A*.) Each spore consists of a single cell.

177. Fern prothallus. — When the spores fall to the ground and conditions are favorable, they start to germinate, and each finally produces a small green, heart-shaped plant known as a *prothallus* (Fig. 83, *C*). The prothallus, though tiny, consists of a great number of cells, some of which form tiny outgrowths from the under surface like root-hairs (called *rhizoids*), which anchor the prothallus to the soil and aid in securing food materials.

On the under surface likewise of each prothallus, in the region of the rhizoids, are minute organs, circular in appearance, known as *antheridia* (spermaries), in which are produced a large number of *sperm-cells* (Fig. 83, *D*, *E*). At a little distance from the antheridia, near the notch in the prothallus, are found other somewhat elongated bodies called *archegonia* (ovaries). In each of these there is developed a special cell known as the *egg-cell* (Fig. 83, *F*).

178. Fertilization of the egg-cells. — When the sperm-cells are ripe, the antheridia or spermaries are ruptured, and the sperm-cells make their way by a curious twisting motion toward the openings on the archegonia. A single sperm-cell moves down the tube of each archegonium, and penetrates the egg-cell, and the two nuclei unite in the process of *fertilization*. (See **91**.) From the fertilized egg-cell develops a fern plant composed of many cells of various kinds, which are all derived from the fertilized egg-cell.

179. Alternation of generations. — Thus we see that in the life-history of the fern plant we have two distinct generations. The first is the ordinary fern plant, which is familiar to all, and which is known as the *asexual generation* or *spore generation*, because the spores formed on the fronds produce the next generation (prothallus) without fertilization or the union of two kinds of cells. The second generation, the prothallus, is the *sexual generation*, because, as we have seen, it can only produce a fern plant from the fertilized egg-cell. In plants like the fern, in which an individual (fern) produces another plant (prothallus) unlike itself, and this in turn gives rise to a plant like the original (fern), we have so-called *alternation of generations*.

180. Suggestions for the study of the fern. — No. 65. If this topic is suggested for study, pupils should be encouraged to collect their own material, noting the surroundings or *habitat* of each kind of fern. They should describe the location, form, and color of each of the nutritive organs, and of the fruit dots, and draw the entire fern. Each student should study a prothallus with a hand magnifier, making an enlarged drawing of the same to show its form and the position and shape of the rhizoids, antheridia, and archegonia. A demonstration of the steps in the life history may well be shown from charts.

B. Mosses

181. The moss plant. — A second group of flowerless plants includes the mosses. In general, mosses are smaller plants than the ferns, but like them are usually found in damp, shady places. If one examines a moss plant when it is " in fruit," a slender stem will be seen projecting from the leafy part below. At the upper end of this slender stem, a covered cup-like structure is evident (Fig. 84, *A*, *k*). This cup, or *capsule* as it is called, is filled with tiny dust-like particles, which when examined with a compound microscope prove to be cells. They are called *spores*. The spores are reproductive bodies similar to those produced in the spore cases of ferns.

182. The moss protonema. — When these bodies are ripe, the capsule opens and discharges some of the spores, which fall to the ground and soon begin to grow, forming at first an elongated cell (Fig. 84, *H*) which later divides, giving rise to two cells. This process continues until a slender, green, thread-like mass is formed, with many branches. This thread-like mass is called the *protonema* (Fig. 84, *G*). Some of the branches produce buds which finally grow into the leafy structure which we know as the moss plant (Fig. 84, *B*, *A*).

183. The sexual generation of the moss. — At the top of some moss plants at certain seasons of the year, in the midst of the rosette of green moss leaves, may be found tiny flask-shaped organs, the *archegonia* (ovaries) (Fig. 84, *F*). At the base of each of these organs is produced an egg-cell. Sometimes in the same moss plant, and sometimes in another, are to be found club-shaped organs called *antheridia* (spermaries) (Fig. 84, *E*). In the antheridia are produced sperm-cells (Fig. 84, *D*). At the proper time the sperm-cells make their way into the archegonia, and when a sperm-cell reaches an egg-cell they fuse, the two nuclei unite, and a fertilized egg-cell is formed. This fertilized egg, by the process of growth and cell division (Fig. 84, *F*, *o*), finally forms the slender stalk with the capsule and spores at the end of it like that referred to in **181** (Fig. 84, *A*, *C*).

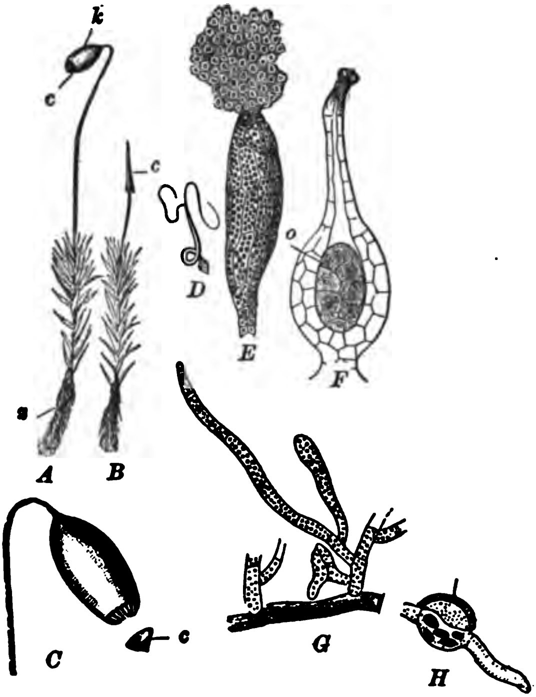


FIG. 84. — Development of a moss plant.

A, moss plant with spore case (*k*) having a lid (*c*); *z*, rhizoids; *B*, young moss plant; *C*, enlarged view of spore case, with lid (*c*) detached; *D*, single sperm-cell; *E*, spermary with escaping sperms; *F*, ovary with dividing egg-cell (*o*); *G*, branching protonema; *H*, spore germinating to form protonema.

184. Alternation of generations in the moss. — The protonema and the leafy shoots with their antheridia and archegonia are known as the *sexual generation* because it is this plant that produces eggs and sperm-cells which must unite before the egg can develop into the spore-bearing plant. The slender stalk with the capsule at the end which is produced by the fertilized egg-cell is called the *asexual generation,* since the spore-bearing plant can reproduce without the union of two kinds of cells. The spore-bearing plant is dependent on the leafy plant for all its food. In the fern, on the other hand, it is evident that the spore-bearing plant and the plant producing eggs and sperms are entirely independent plants. In both of these groups of seedless plants, however, there is an alternation of generations.

185. Suggestions for the study of mosses. — No. 66. The teacher should secure plenty of material for the demonstration both of the plants with spore cases and if possible the plants with archegonia and antheridia. On account of its size the pigeon wheat moss is desirable. The material may be collected and dried, since both generations are not likely to be obtained at the same time of year. If spore cases are on hand, the work might then be done when the sexual plants can be secured in a fresh condition. The pupil should describe and draw the leafy moss plant. The location of archegonia and antheridia should be stated. Then the spore-bearing plant should be described, together with the relation to the sexual plant which produced it, and the spore case opened to show the spores. The two plants should then be drawn and labeled.

C. *Algæ*

186. Spirogyra. — Any one who has ever been in parts of the country where ponds or very slowly moving bodies of water abound must have noticed either at the bottom or on the surface of the water a green, slimy mass. It is so frequently found on the surface that it is called "pond scum." If one examines a small portion of this mass even with the naked eye, one will see that it consists of a great number of interlacing threads. When looked at with the compound microscope each of these threads is seen to be a series of cells joined end to end. All the cells are practically the same in shape and structure, however, so that a study of one will make clear the structure of all.

Inclosing each cell there is a thin cell wall. The first structures one is likely to notice within the cell are the chlorophyll bodies. In the pond scum known as Spirogyra the chlorophyll is arranged in spiral bands, and it is this which has given the plant its name (Fig. 85, *B*). In other forms the chlorophyll is differently arranged, sometimes in star-shaped masses, one in each half of the cell, and sometimes diffused throughout the cell. If a little iodine is added to the specimen when it is being examined under the microscope, a nucleus may be distinguished near the center of each cell (Fig. 85, *B*). In the cell-body and nucleus the protoplasm appears as a clear and almost transparent mass.

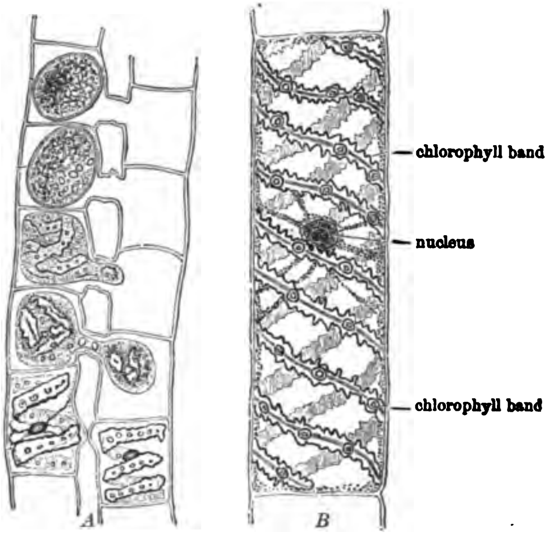


FIG. 85. — Spirogyra. — (Strasburger.)
A, two conjugating threads of Spirogyra ; *B*, single cell of Spirogyra.

The thread or filament continues to increase in length by the growth and division of certain individual cells that compose it. At the close of the season most of the filaments perish, but some of them undergo peculiar changes. The bands of chlorophyll lose their definiteness, the protoplasm becomes massed, tiny outgrowths from the sides of the cells occur, and these continue to extend till they meet similar outgrowths from a neighboring filament (Fig. 85, *A*). These outgrowths unite, and thus a tube from one cell to the other is formed. The contents of one cell pass through to another, and the two masses fuse. A thick wall forms about the united mass and the old cell walls decay and fall away, leaving these thick-walled *zygospores* on the bottom of the pond. In the spring the protoplasm within each of these zygospores begins to grow, breaks through the thick wall, and proceeds to form a new filament by cell division. The formation of the zygospores is known as *conjugation;* it is a kind of sexual reproduction, though the two cells taking part in the process are the same in appearance.

If one observes pond scum on a sunny day, bubbles will be seen escaping from the mass. A test of this gas proves it to be oxygen, and as we should expect, it occurs in connection with the process of carbohydrate manufacture the same as in other green plants. In fact it has been proved that these simple plants manufacture foods, digest, assimilate, respire, and reproduce as do the higher plants we have studied. The differences, then, between a simple plant like Spirogyra and a bean plant or an oak tree are mainly those of structure and adaptations for the performance of functions which are largely common to both. Indeed, it is evident that every cell of the Spirogyra is in contact with the water, from which all the substances needed are obtained by absorption. Hence, any special adaptations for securing food materials or of giving off wastes, such as are found in higher plants, are unnecessary.

187. Suggestions for the study of Spirogyra. — No. 67. It is desirable that pupils should see the "pond scum" in its habitat, even if they do not collect material for work. The escape of bubbles may be noticed at this time or in the laboratory. The mass should be described as to color and "feel," and the fine threads noted by floating the mass in a saucer of water. A filament should then be studied under the microscope, and the parts of a single cell described, and several cells should be drawn. If fresh zygospore material can be obtained, this should also be studied, and the parts described above noted and drawn; otherwise charts or pictures may be used.

188. Pleurococcus and other algæ. — Another and still simpler form of plant life is known as Pleurococcus. It may be readily obtained from the trunks on the north side of large trees. It appears as a very thin green layer closely adhering to the bark. If a little of this material is scraped off and placed under the compound microscope, it will be found that it is made up of a large number of tiny circular green cells which adhere to each other more or less, since in the process of reproduction one cell divides to form two, each of which is considered to be an individual plant. Thus the whole mass is made up of a large number of one-celled plants.

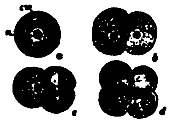


FIG. 86. — Pleurococcus. — (Sedgwick and Wilson.)

The Spirogyra and Pleurococcus are only two of a large number of simple plants known as algæ. They differ widely in form, but none of them develop roots, stems, or leaves. Among the most common algæ are the marine forms known as sea weeds, of which there are many kinds.

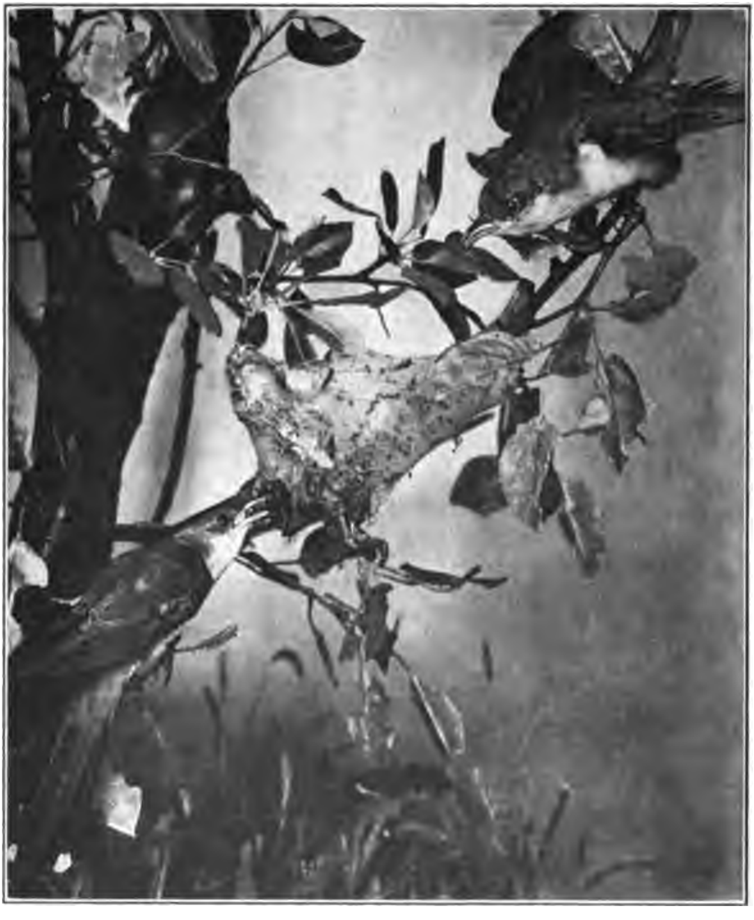
189. Suggestions for the study of Pleurococcus. — No. 68. As indicated above, material for the study of Pleurococcus may be easily obtained by removing pieces of bark from trees having a considerable quantity of this plant on their surface. If collected in a dry season, the bark should be placed under a bell-jar with sufficient water to make the air moist, and allowed to stand for several days. The place in which the Pleurococcus is found should be described, and also the appearance of a mass of the plants. Single cells should then be studied under the high power of the compound microscope, and the cell and its contents described and drawn.

D. Fungi. (*See Chapter IX*, 147–166.)

III. SUMMARY OF A CLASSIFICATION OF THE PLANT KINGDOM

Division I — *Spore-producing plants.*
  Sub-division 1 — *Fungi* (including bacteria, yeast, molds, mushrooms, rusts, smuts).
  Sub-division 2 — *Algæ* (including Spirogyra, Pleurococcus, and sea weeds).
  Sub-division 3 — *Mosses* and their relatives.
  Sub-division 4 — *Ferns* and their relatives.

Division II — *Seed-producing plants.*
  Sub-division 1 — *Gymnosperms* (including pines, spruces, hemlocks).
  Sub-division 2 — *Angiosperms*, composed of:
    Class I — *Monocotyledons* (*e.g.* corn, lilies, gladiolus).
    Class II — *Dicotyledons* — composed of 160 or more families, one of which is
      Rose *family* — composed of 14 genera, one of which is the
        Pear *genus* — composed of 3 species, one of which is the —
          Apple *species*, of which there are many *varieties*, *e.g.* Baldwin, Greening, etc.



YELLOW-BILLED CUCKOOS EATING TENT CATERPILLARS

Photographed from exhibit in Brooklyn Museum of Arts
and Sciences, by A. E. Rueff.

ANIMAL BIOLOGY

CHAPTER I

INSECTS

I. BUTTERFLIES AND MOTHS

1. Insect net. — Since most butterflies and moths are more or less injurious, at least in their caterpillar stage, boys and girls should be taught that they are benefiting their community by catching and killing these insects in a painless manner. For this purpose an insect net and a poison bottle are necessary. An insect net may be made by securing a yard of galvanized iron wire (No. 3), bending it in the form of a ring (thus Ω), and inserting the two ends of the wire in one end of a light wooden rod about three feet long. To the wire ring should be sewed a bag about two feet deep made of cheesecloth or bobinet (Fig. 1). To catch a butterfly or other insect, wait until it alights, then quickly place over it the opening of the net, holding up the closed end of the net till the insect flies to the top. Now place beneath the insect the open mouth of a poison bottle prepared as follows, and after the insect is in the bottle quickly replace the cover.

2. Poison bottle. — Secure a pint fruit jar or a wide-mouthed bottle fitted with a cover. Into the bottom put a spoonful of more or less pulverized potassium cyanide. Thoroughly mix some plaster of Paris in water and thus make a thin paste. Carefully pour the liquid into the jar until it forms a layer about an inch thick. When this hardens, it covers and holds the cyanide in place, but it is porous enough to allow fumes to escape, which kill most insects in the closed space in a few moments. The bottles are perfectly safe in the hands of pupils. Care should be taken, however, not to handle the cyanide or to breathe in the fumes. The bottle

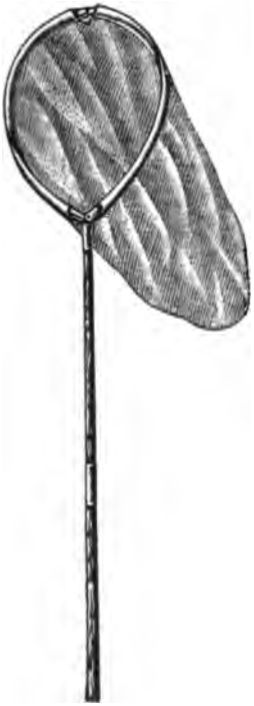


FIG. 1. — Insect net.

should be kept tightly closed when not in use, and should be distinctly labeled "*Poison Bottle*" (Fig. 2). If the bottle is broken, the pieces of glass and all the contents should be buried in the earth.

3. Preparation of butterflies for study or for collections. — For laboratory study it is desirable to use the largest butterflies obtainable. The work will be carried on to much better advantage if there is at least one mounted specimen for each two pupils. These should be prepared with the wings fully extended, with the legs spread out as in walking, and with the proboscis partly uncoiled. To get the material in this shape place two books about half an inch apart on a soft board; run an insect pin through the thorax of a freshly killed insect, extend the legs and proboscis, then put the body of the insect between the two books, thrusting the tip of the pin into the board beneath. Spread out the fore wings on the book covers so that their hind margins are at right angles to the thorax, pull the hind wings outward into their natural position when at rest, and hold the two pairs in place with pieces of glass till the specimen has dried. Butterfly spreading boards may be bought or made (Fig. 3).

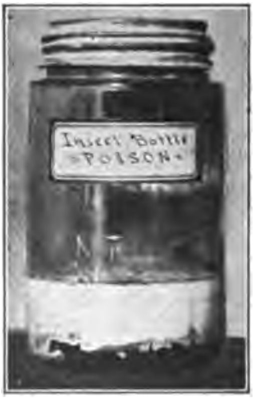


FIG. 2. — Poison bottle for killing insects.

Dry specimens may be relaxed by placing a quantity of sand or crumpled paper in a battery jar or other wide-mouthed receptacle that can be tightly covered. Wet the sand or paper thoroughly and then sprinkle over it a little dry sand or cover with blotting-paper.

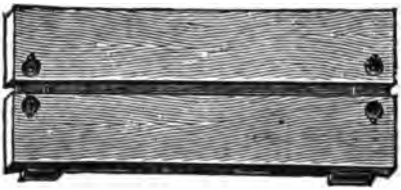


FIG. 3. — Insect spreading board.

Put in the dried butterflies about twenty-four hours before they are to be spread, and cover the dish. If the relaxing jar is kept in a warm place, the process will be hastened, but care should be taken not to leave the insects in the moist chamber long enough for mold to grow upon them. It is of course better to mount the butterflies as soon as they are killed.

4. Insect boxes. — A box for displaying a butterfly for class study may be made as described below by any fourteen-year-old boy; these cases will preserve the insects from year to year, thus saving labor as well as insuring good material that pupils can examine from both sides. The boxes may likewise be used as cages for the study of the activities of live grasshoppers, caterpillars, or other insects. After butterflies have been studied they should be transferred to an insect case or other moth-proof box, a piece of cotton soaked in carbon bisulphide should be inserted, and the box kept tightly closed till the butterflies are again needed. "Chiclet" boxes, since they have glass covers, may be used for storing and displaying the insect collections that may be made by pupils. A layer of absorbent cotton over the bottom of the box makes a good background (Fig. 4).

To make the insect boxes, secure from a mill or a local carpenter strips of wood 2½ inches wide and ½ inch thick, with grooves ⅛ inch wide and ⅛ inch deep, cut a quarter of an inch from the two margins of one side. About 18 inches will be required for each box. For the sides saw up two pieces each 5½ inches long, and for the ends the

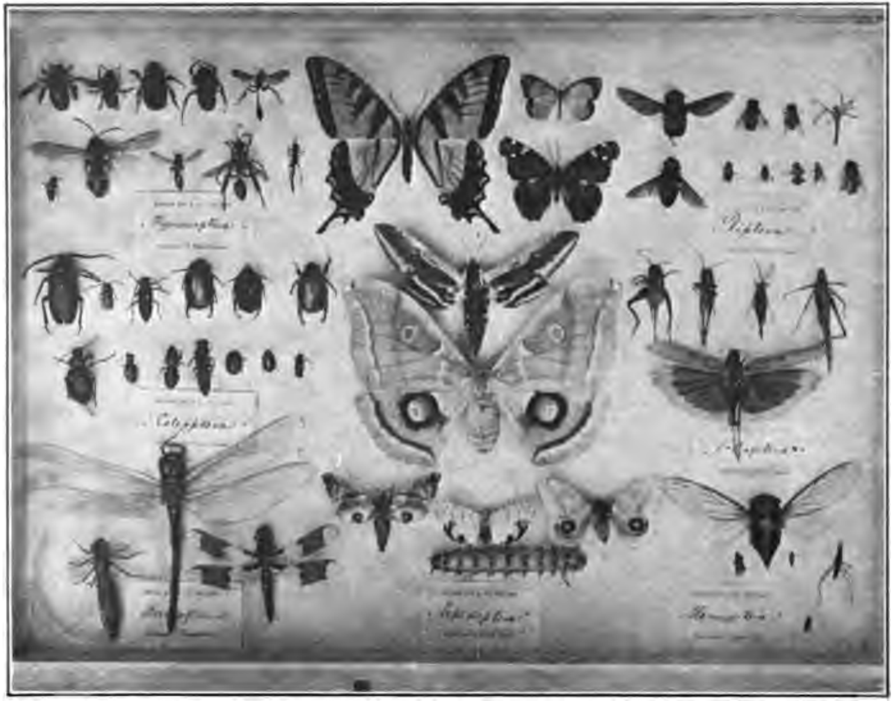


FIG. 4. — Insect collection. (Prepared by Kny-Scheerer Co. Photographed by E. R. Sanborn, N. Y. Zoölogical Park.)

pieces should be 3¾ inches in length. One of the ends should be planed down to a width of 1¾ inches (the distance between the grooves). Nail the four pieces together and insert in the grooves on each side a cleaned 4 × 5 picture negative, the gelatin of which may be easily removed with hot water. Glue to the center of one of the glasses a piece of cork to hold the insect pin, and fasten a piece of wood to the narrow end by a wire nail, which will prevent the glasses from slipping out but will still allow the box to be opened. The boxes are made more attractive if they are treated with dark oak jap-a-lac or stain (Fig. 5).

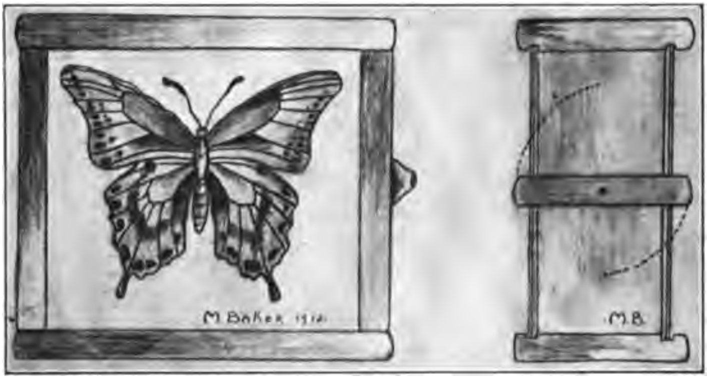


Fig. 5. — Insect box.

5. Experiments with living butterflies. — Before trying the feeding experiments, the butterflies should be kept for at least twenty-four hours without food. After a butterfly has fed, it should be placed by itself, since the same insect may be unwilling to eat a second time. Have as many students at a time see the feeding as can well do so; this will save time, and fewer butterflies will be needed. The mourning cloak, monarch, and violet tip butterflies are satisfactory for this experiment. Place the butterfly on a stick or other rough object, and put the tiny drop of honey near it. This may be done in a cage, or under a glass jar, or in the open laboratory.

In the latter case the windows should, of course, be closed, and this should also be done while watching the insect fly. The flying and feeding experiments with insects make excellent home work if the pupils can readily obtain the live material. Children in New York City have caught and kept butterflies for several months, feeding them twice or three times a week.

6. **Study of a butterfly.** — Laboratory study.

A. *Regions and appendages.*

Examine a butterfly and distinguish (1) the front or *anterior* (Latin, *ante* = before) region called the *head;* (2) the middle region called the *thorax;* and (3) the hind or *posterior* (Latin, *post* = behind) region known as the *abdomen.*

1. Which region is the smallest? Which is the widest? Which region is longest?
2. To which region are the *appendages* (legs and wings) attached?
3. Which region seems to have no appendages?

B. *Organs of the head; feeding.*

1. Observe two long, slender appendages attached to the head; they are called *antennæ* (singular, *antenna*). State the position of the antennæ on the head. Describe the shape of an antenna, stating where it is the thicker (*i.e.* at the *proximal* end, which is next the head, or at the *distal* end, which is farthest from its attachment to the head).
2. Near the base or proximal end of the antennæ find the large *eyes.* State their position on the head, their shape, and their size (as compared with the rest of the head).
3. Demonstration. Take a living or a relaxed specimen of the butterfly, and with the help of a dissecting needle find a coiled structure on the lower or *ventral* surface of the head. It is the *sucking tube* or *proboscis.* Gently uncoil it and describe this feeding organ as to position and appearance.

4. (Optional demonstration or home work.) Place a tiny drop of honey or molasses diluted with water near a butterfly. If the insect does not seem to realize the presence of the sweet substance, touch the proboscis with the needle, or if necessary put the needle into the coil of the proboscis, and gently unroll it.
   - *a.* Describe what you have done to get the animal to eat.
   - *b.* Describe the movements of the proboscis.
   - *c.* What reason do you find for supposing that the butterfly is feeding?
   - *d.* What reason have you for thinking that the proboscis must be hollow?
5. (Optional.) Between the two antennæ, and projecting upward in the anterior region of the head, are two slender structures covered with hair; they are the *labial palps.* In some butterflies the labial palps are inconspicuous. If they show in your specimen, describe them as to their position and appearance.

C. *Organs of the thorax; locomotion.*

1. How many pairs of wings has the butterfly?
2. Describe a wing as to comparative length, breadth, and thickness.
3. Hold a butterfly between your eyes and the light, and study carefully the course of the veins in the two wings on one side. Toward what region of the wings (*i.e.* proximal or distal) do the main veins converge?
4. Bend the veins and the connecting membrane in a wing that is given you.
   - *a.* Which is the more rigid?
   - *b.* What, then, is one use of the veins?
5. Take a small piece of the wing of a butterfly that is given you and rub the surface with your finger tip.
   - *a.* Describe what you have done, and state how the substance on your finger compares in color with the color of the part of the wing before it was rubbed.

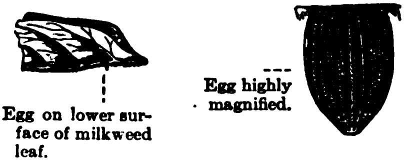
b. (Optional.) Shake some of the powder from a wing upon a glass slide and examine it with a low power of the compound microscope. The bodies that you see are called *scales*. At one end of each scale you should find a tiny stem by which the scale was attached to the wing, and at the other end usually one or more notches. Describe the shape of the scales that you are studying, and make a sketch of one of them much enlarged.

6. (Optional home work.) Watch a butterfly in the field as it moves the wings in the act of flying.
   a. Will the downward stroke of the wings tend to lower or to raise the body?
   b. What effect will the upward stroke of the wings tend to have?
   c. In which of these two directions, therefore, must the butterfly strike the harder and more quickly in order to raise the body in the air?
   d. Since the weight of the body tends to bring the animal to the ground, in which direction must the insect strike with the greater force in order to keep itself at a given level in the air?

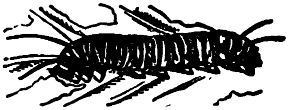
7. Some butterflies have a tiny pair of front legs that are usually folded against the thorax; so that you need to look very carefully before deciding as to the number of legs present.
   a. How many pairs of legs has this insect?
   b. Are the legs long and slender or short and thick?
   c. Is each leg all one piece or is it jointed as in the human body?
   d. Examine the lower end of a leg and state how the foot is adapted for clinging to flowers.

D. Make a drawing, natural size, of the upper or *dorsal* surface of a butterfly. Label antennæ, eyes, proboscis, head, thorax, abdomen, wings, principal veins of one wing.

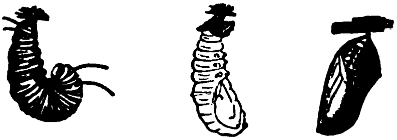
7. General characteristics of butterflies. — All butterflies, as we shall see later, are constructed on much the same general plan as that of other insects; *i.e.* their bodies are divided into three regions, head, thorax, and abdomen; on the head are two antennæ and a pair of large eyes; on the thorax are two pairs of wings and three pairs of jointed legs; and the abdomen is composed of a number of parts called rings or *segments* (Fig. 6).


Egg on lower surface of milkweed leaf.
Egg highly magnified.

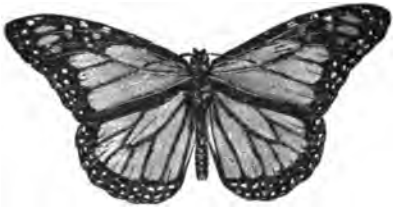
Egg stage.



Larva stage (caterpillar).



Development of pupa stage.



Adult Stage.

Fig. 6. — Life history of monarch butterfly. (Weed.)

8. Wings and their scales. — While this general plan of structure is common to all insects, there are certain marked peculiarities that enable one readily to recognize a butterfly.

For instance, although other insects have two pairs of wings, no others have these organs so beautifully colored and relatively large. This color of the wings is due (we proved in **6**, *C.* 5) to tiny bodies called *scales.* If the wing of a butterfly is rubbed, the color comes off and the wing at that point loses its color. To the unaided eye this colored substance from the wing appears to have no definite form; in fact, it looks like the pollen from flowers. An examination with the compound microscope, however, shows that each of these tiny bodies has a definite shape (Fig. 7). Each scale has at one end a tiny stem, but in other respects they vary considerably in form.

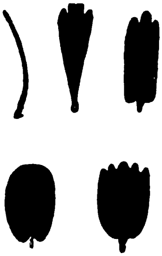


FIG. 7. — Scales from wing of a butterfly.

The scales are attached in the following manner. In the membrane of the wing are openings into which fit the stems of the scales. The latter are arranged in rows and overlap something like the shingles on a roof (Fig. 8). In spite of this arrangement it is evident that the scales are not firmly attached, since the slightest touch is sufficient to dislodge many of them. Rough handling was not apparently planned for in the construction of these insects. The presence of these scales on the wings of butterflies and of their near relatives, the moths, is so characteristic that these insects have been called the *Lepidoptera* (Greek, *lépido* = scale + *ptéra* = wings). Not only are scales found on the wings but, in the shape of hairs, they form a fuzzy growth over the surface of the whole body.

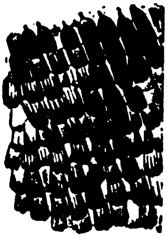


FIG. 8. — Piece of the wing of a butterfly with scales. (Coleman.)

9. Proboscis. — Another marked characteristic of butterflies and moths is the sucking tube, or *proboscis*. While the proboscis seems to be a single structure, in reality it is composed of two slender appendages, each having a groove on its inner surface; so that, when the two parts are brought together, they form a tube through which the butterfly sucks nectar from flowers. When the proboscis is not in use, the butterfly rolls it into a tight coil underneath the head (Fig. 9).

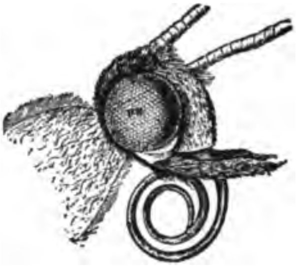


Fig. 9. — **Head of butterfly. (Coleman.)**

10. Legs. — The legs of a butterfly are not very strong, since they are relatively so long and slender. This is perhaps the reason why these insects seldom use them for walking. They are, however, very useful in clinging to flowers. The two curved claws on the tip of each foot show clearly the means by which the animals are able to hold on to the plants on which they usually alight.

11. Reproduction and life history of butterflies. — As in the reproduction of plants, the development of the butterfly begins with a special cell known as an *egg-cell.* These egg-cells are formed in the body of the female insect. When these egg-cells have been fertilized by *sperm-cells* from the male butterfly, which correspond to sperm-cells of the pollen grains (**P. B.**[1], **91**), the eggs are deposited on the under side of the leaves of plants on which the young can feed (Fig. 6). These egg-cells divide and subdivide, till at last a many-celled organism is developed that is commonly called a "worm," but that is more correctly known as a *caterpillar* (Fig. 6).

The tiny caterpillar emerges from the covering of the egg and begins to feed upon the leaf. As it feeds it grows, and from time to time sheds or *molts* the more or less hardened skin that covers the whole insect. At last, after several molts, the caterpillar reaches its full size and then stops eating. At no time in the growth of the caterpillar would one be likely to mistake it for a butterfly (Fig. 6). It has no wings, no antennæ, and instead of a proboscis one finds a pair of strong jaws with which it eats leaves. The distinction between thorax and abdomen is not at all clear, and at first sight it seems to have more legs than a butterfly. The three front legs are really jointed, but they are so short and thick that there seems to be no resemblance between them and those of a butterfly. The other pairs of legs, varying in number, are not jointed structures, and hence are not really legs at all.

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[1] **P. B.** = "Elementary Plant Biology," by the authors of this book.

The mature caterpillar now attaches itself to some object and, after molting once more, usually assumes quite a different shape from that of the caterpillar, and forms about itself a hardened skin within which a marvellous transformation occurs (Fig. 6). The long, coiled tube takes the place of the jaws as a feeding organ, and long, slender, knobbed antennæ appear on the head; two pairs of beautifully colored wings develop on the thorax, as well as the three pairs of slender, jointed legs; and at last the fully developed butterfly breaks through the covering that held it and flies away.

It is evident, then, that a butterfly passes through several fairly distinct stages. First we may distinguish the *egg stage*, then the caterpillar or *larva stage*, which is followed by the transformation stage in which it is called a *pupa*. The pupa of a butterfly is often called a *chrysalis* (Greek, *chrýsos* = gold) on account of the golden spots of color on many pupa cases. Lastly we have the fully developed or *adult insect* that emerges from the pupa stage.

12. Distinguishing characteristics of moths. — The moths and butterflies belong to the same order of insects; that is, the scaly winged insects. But there are some characteristics in which these two kinds of insects differ. For instance, moths when at rest fold the wings horizontally (Fig. 11), while butterflies fold them vertically, that is, erect (Fig. 10). The wings, too, of moths are not usually as brilliantly colored. Most moths fly at night, while butterflies are day-flyers. The body of moths is usually relatively broader than that of butterflies. Moth antennæ are of various shapes, often like a feather, but never knobbed.

In general, the life history of moths is very much the same as that of butterflies, but the larvæ of many moths spin a more or less silky mass of threads about themselves, as is the case with the silkworm caterpillar (Fig. 16), and this outside covering of the pupa stage is known as the *cocoon.*

13. Economic importance of butterflies and moths. — The larvæ of both butterflies and moths are voracious feeders, as any one knows who has had any experience with caterpillars. In fact, they may be called animated feeding machines, since the animal must not only provide for its own growth, but must also store up enough food to form the new parts such as the wings and the legs. Not all larvæ of butterflies and moths are considered harmful, however, since some of them are not prolific enough to have any serious effect upon vegetation, which is the source of food of most caterpillars. This is true of many of the butterfly larvæ and of some moth larvæ. Then, too, some of the larvæ feed on plants that are not useful to man. This is true of the larva of the monarch butterfly (Fig. 6), which feeds upon leaves of the milkweed. The adult butterflies and moths of course are not capable of doing any harm since, when they eat anything at all, they most commonly suck the nectar of flowers. When the flowers are visited in this way, they are very likely to be cross-pollinated and thus are benefited instead of injured. But in general the moths and butterflies play but little part in the very important process of cross-pollination of flowers, most of this work being done, as we shall soon learn, by the bees. The following are a few of the injurious forms of butterfly and moth larvæ.

14. Cabbage butterfly. — This is one of the few forms of butterfly larvæ that are of sufficient economic importance to be worthy of mention. Any one who has been near a cabbage patch will remember to have seen many rather small white butterflies (Fig. 10) hovering about among the cabbages. These are the cabbage butterflies depositing their eggs on the under side of the leaves. The small green caterpillars that develop from the eggs very soon show what they can do in the way of eating. The ragged appearance of the young leaves is a warning to the gardener to "get busy" if he desires a crop. The caterpillars do most harm when the cabbages are young, since these plants may be so injured as to be unable to form heads. The caterpillars are often killed by sprinkling with a mixture of Paris green and arsenate of lead in water (**47**). This mixture should not be used, however, after the heads begin to form, on account of the possibility of the poison collecting between the leaves of the head, with consequent danger to the consumer.

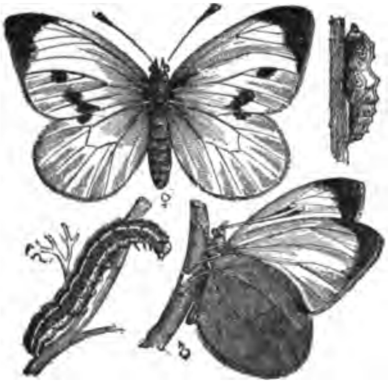

FIG. 10. — Life history of cabbage butterfly. (Coleman.)

15. Tussock moth. — The caterpillars of the tussock moth attack our shade trees. Where they are unchecked, they will practically strip the trees of their leaves. The female moth is wingless (Fig. 11). When she emerges from her cocoon, she lays a mass of eggs upon the outer surface of the cocoon and secretes about them a white foamy mass which hardens (Fig. 11). If this occurs in the autumn, the eggs

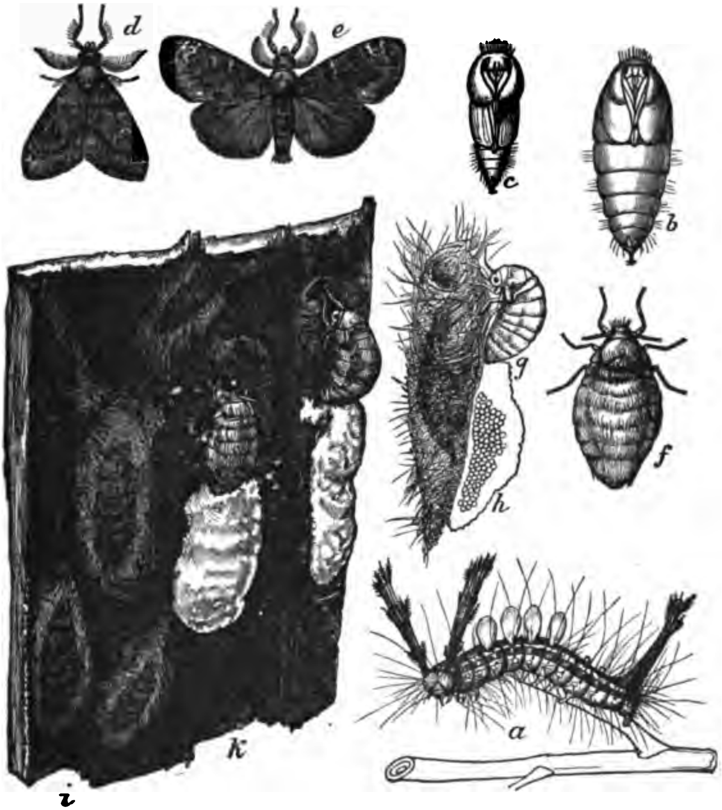

FIG. 11. — Life history of tussock moth. (Osborn.)

remain during the winter, and the following spring hatch out. The young caterpillars attack the leaves of the tree on which they have hatched out, or if the cocoon was placed elsewhere, they crawl up the nearest tree and start business at once. They are great travelers, and this is the way they spread through a neighborhood, since, as already mentioned, the female cannot fly. To capture these insects one may place a band of cotton batting around the trunk of each of the trees one wishes to protect. The larvæ do not usually crawl over this but will, if mature, proceed to pupate underneath the band. All pupæ and egg masses should be collected (Fig. 12) and burned. This is about as much as the individual can do. Where a spraying apparatus is available the trees should be sprayed with lead arsenate, thus killing all the caterpillars. This caterpillar is rather handsome as caterpillars go, having a bright red head and a series of yellow tufts of hair on the dorsal part of the body (Fig. 11).

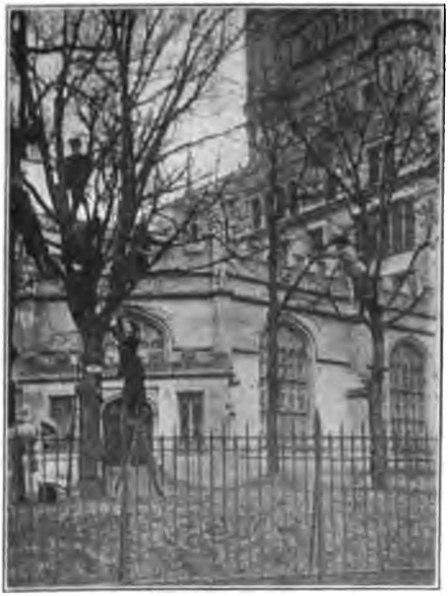
FIG. 12. — Morris High School boys removing 63,020 eggs of tussock moth from four trees on school grounds. Work directed by Paul B. Mann. (Photographed by Lewis Enowitz.)

16. Gypsy moth and brown tail moth. — The gypsy moth (Fig. 13) was brought into Massachusetts from Europe in 1869 in connection with scientific experiments. Some of these specimens acci-

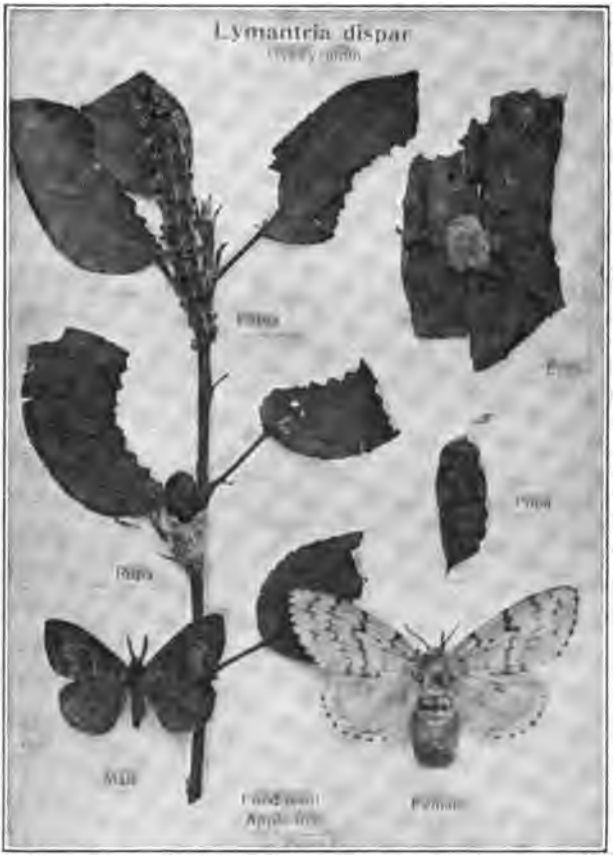

FIG. 13. — Life history of gypsy moth. (Prepared by Kny-Scheerer Co. Photographed by E. R. Sanborn, N. Y. Zoölogical Park.)

dentally escaped and gradually increased until the damage to fruit, forest, and shade trees caused by the larvæ was so evident that property owners had to call upon the state to aid in their extermination. Nearly one million dollars was expended during a period of ten years. At the end of this time the number of the insects was so reduced that it was impossible to convince taxpayers of the necessity for further appropriations to complete the extermination. Since then the gypsy moths have spread over the whole state of Massachusetts and into the adjoining states.

The larvæ of another moth, the brown tail, has likewise caused great damage in the New England states. The New York State Department of Education is sending out colored pictures of the life history of both of these insects with the following statement regarding them. " Warning — Take Notice. There is grave danger of both of these dangerous pests being brought into New York State. They have destroyed thousands of trees in Massachusetts, and they will do the same in New York unless checked. All are hereby urged to become familiar with the general appearance and work of these two insects, and to report anything suspicious to the State Entomologist, Albany, N.Y., sending specimens if possible. Abundant hairy caterpillars an inch to two inches long on or in the vicinity of defoliated trees should lead to investigation."

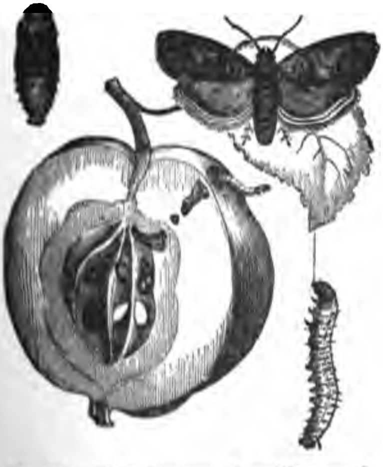

FIG. 14.—Life history of codling moth. (U. S. Dept. of Agriculture.)

17. Codling moth.— Every one has eaten into apples that have been injured by the " apple worm," which is the larva of the codling moth (Fig. 14). The damage to the fruit crop from this insect in New York State alone is estimated at three million dollars each year. According to Professor Hodge (" Nature Study and Life ") the codling moth "was early imported from Europe and is now at home wherever fruit is cultivated in this country and Canada, causing a loss of from 25 to 75 per cent of the apple crop, as well as that of many other fruits. In the heavy bearing years the wormy apples fall off and are discarded, but the great number of apples serves to rear enormous numbers of the worms, and, according to my observations and experience, in the off years, when apples would be valuable, the worms take the whole crop.

"The larvæ change to pupæ in May, emerge as moths in late May or June, and lay their eggs for the first brood in June. The larvæ generally crawl into the calyx cup of the young apples and eat their way to the core, complete their growth in about three weeks, commonly eat their way out through the side of the apple, and either spin to the ground and crawl to the trunk of the tree or crawl down the branches and make their cocoons under the bark again. This occurs with the greater number early in July. This habit affords one of the most vulnerable points of attack. To trap practically all the codling moths in an orchard it is only necessary to scrape all loose bark off from the trees and fasten around the trunks a band of burlap or heavy paper. Remove the bands and collect all larvæ once a week during July." The practice of most commercial growers at the present time, however, is to depend very largely or entirely on spraying with a poison (*e.g.* arsenate of lead, **47**). One application, even, a week or ten days after the blossoms fall, if thorough, will frequently give 95 per cent to 98 per cent of sound fruit.[1]

18. Clothes moths. — "The little buff-colored clothes moths (Fig. 15) sometimes seen flitting about rooms, attracted to lamps at night, or dislodged from infested garments or portières, are themselves harmless enough, for their mouth parts are rudimentary, and no food whatever is taken in the winged state. The destruction occasioned by these pests is, therefore, limited entirely to the feeding or larval stage. The killing of the moths by the aggrieved housekeeper, while usually based on the wrong inference that they are actually engaged in eating her woolens, is, nevertheless, a most valuable proceeding, because it checks, in so much, the multiplication of the species which is the sole duty of the adult insect.

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[1] The authors are indebted to Mr. E. P. Felt, state entomologist of New York, for this and several other suggestions relating to insects.

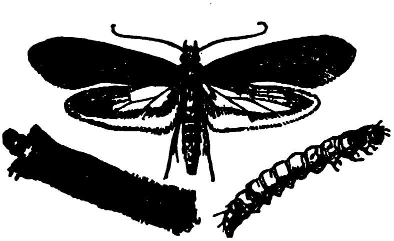

FIG. 15.—Life history of clothes moth. (U. S. Dept. of Agriculture.)

"There is no easy method of preventing the damage done by clothes moths, and to maintain the integrity of woolens or other materials which they are likely to attack demands constant vigilance, with frequent inspection and treatment. In general, they are liable to affect injuriously only articles which are put away and left undisturbed for some little time. . . . Agitation, such as beating and shaking, or brushing, and exposure to air and sunlight, are old remedies and still among the best at command. Various repellants, such as tobacco, camphor, naphthalene cones or balls, and cedar chips or sprigs, have a certain value if the garments are not already stocked with eggs or larvæ. . . . Furs and such garments may be stored in boxes or trunks which have been lined with the heavy tar paper used in buildings. New papering should be given to such receptacles every year or two."[1]

19. Silkworms.—One species of moth, the silkworm (Fig. 16), is of great economic importance to man. The larva of this insect feeds upon the leaves of the mulberry tree, and after reaching maturity it spins a cocoon, requiring about three days for its completion. The silk is obtained by heating the cocoon in ovens to kill the pupa, and then by reeling off the silk and spinning it into threads. "For many hundreds of years the cultivation of the silkworm was confined to Asiatic countries. It seems to have been an industry in

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[1] Circular No. 36, Second Series, United States Department of Agriculture.

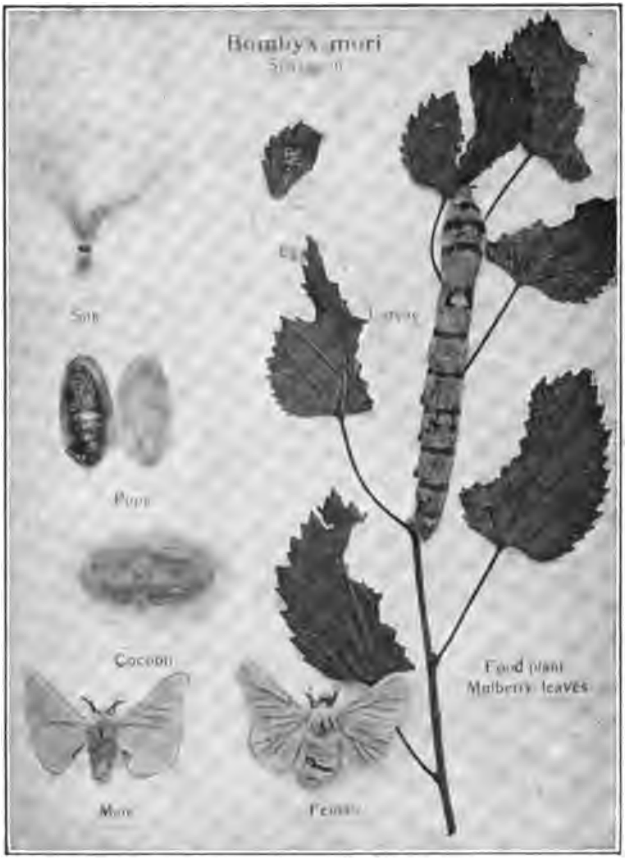

FIG. 16. — Life history of silkworm moth. (Prepared by Kny-Scheerer Co. Photographed by E. R. Sanborn, N. Y. Zoölogical Park.)

China as early as 2600 B.C., and was not introduced into Europe until 530 A.D. After the latter date the culture rapidly increased, and soon became prominent in Turkey, Italy, and Greece, and has held its own in those countries, becoming of great importance in Italy. . . . Japan to-day produces a very considerable proportion of the world's supply of raw silk. Thus of the $41,000,000 spent by the United States for raw silk in 1902, more than $20,000,000 went to Japan."[1] Many attempts have been made to introduce this industry into the United States, but the experiments thus far made have been rather unsuccessful.

II. GRASSHOPPERS AND THEIR RELATIVES

20. Study of the grasshopper. — Laboratory study.

A. *Regions and appendages.* — Examine a grasshopper and distinguish the three regions of the body proper: (1) the front or *anterior* region called the *head;* (2) the middle region called the *thorax;* and (3) the hind or *posterior* region known as the *abdomen.* (The anterior region of the thorax is covered by a cape or collar.)

1. Which region is the smallest? Which is the widest? Which region is the longest?
2. Which region has legs and wings attached to it?
3. Which region is made up of a number of similar rings or *segments?*

B. *Organs of the head; feeding.*

1. Notice two long, slender feelers on the head. They are known as *antennæ* (singular, *antenna*). State the position of the antennæ on the head and describe their shape.
2. Describe the shape and position of the large eyes. State their relative size compared to that of the head.

3. (Optional.) Cut off with a sharp knife a thin slice from the outer surface of one of the large eyes. Remove all the soft, dark material from the inside. Place the

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[1] Bailey's Cyclopedia of Agriculture, Vol. III, p. 640.

cleaned piece on a glass slide and examine the outer (convex) surface with the low power of the compound microscope. Look for the boundary lines of many several-sided areas. Each of these areas is called a *facet*. Each facet is the covering of one of the parts of which the *compound eye* is composed.

a. Describe the preparation of the slide for examination.

b. Describe the shape of each of the facets, and make an outline drawing of three of them, much enlarged, to show the way in which they fit together.

4. (Optional.) With the aid of a magnifier look for a tiny eye in the middle of the front part of the head. There is a similar eye between each compound eye and the antenna of the same side. These eyes are *simple eyes*. Describe the simple eyes as to location, number, and relative size.

5. Find the *upper lip* (*labrum*) on the lower anterior part of the head. Describe its location and shape.
6. (Demonstration.) Raise the upper lip of a large grasshopper and find the *jaws* or *mandibles* beneath it. With a dissecting needle gently pry the jaws a little way apart. Do the jaws move from side to side or up and down?

7. (Optional.) Find the *lower lip* on the under side of the head, *i.e.* next to the thorax. It is divided vertically into two equal parts. Attached to either side are two tiny, jointed structures called *labial palps*.

a. Describe the location of the lower lip (*labium*).

b. Describe the position and appearance of the labial palps.

8. (Optional demonstration.) Between the jaws and the lower lip of a large specimen find a pair of appendages each of which is made up of three parts that are joined together at the base: (1) on the outside is a several-jointed feeler or *maxillary palp;* (2) next is a spoon-shaped body; and (3) a curved and sharp-pointed

body. It will be necessary to pull sideways on the mouth parts to see this inner part. These three parts form one appendage called the *maxilla* (plural *maxillæ*), or helping jaws.

When you have found these three parts of a maxilla, describe them.

9. (Demonstration or home work.) Place several grasshoppers in a cage or a glass jar with moistened leaves of clover, grass, or lettuce. If these insects refuse to eat, try others till you find some that will eat.
   - *a.* Describe the movements of the head and also the movements of the mouth parts while the grasshopper is eating.
   - *b.* Which mouth parts must do most of the biting of the leaf? Give reason.

10. (Optional.) Make a drawing, at least four times natural size (× 4) of the face view of a grasshopper. Label antenna, compound eye, simple eye, upper lip.

C. Organs of the thorax; locomotion.

1. How many legs has a grasshopper? Which pair is the largest?
2. Make a sketch (× 4) to show the following parts of one of the hind legs: (1) a large segment nearest to the thorax, the *thigh* or *femur;* (2) the next segment to the femur, the *tibia;* (3) the part that rests on the ground when the insect walks, the *foot* or *tarsus.* Use a magnifier to see the several segments in the tarsus, the little claws at the tip end. and a little pad between the claws. Label femur, tibia, segments of the tarsus, claws, pads.

3. (Optional.) Make a sketch (× 4) of one of the smaller legs to show the size and shape of the parts. Use th same labels as in the drawing of the hind leg.

4. Get a grasshopper to climb up a stick or piece of grass.
   a. Tell what you have done and observed.
   b. How is the insect able to cling to the stick?
5. (Demonstration or home work.) Place a lively grasshopper in a clear space on the floor or in a cage. Get it to jump enough times to determine the following points: —
   a. What is the position of the parts of the hind legs when the animal is ready to leap?
   b. What is the position of the parts of the hind leg the instant the insect lands?
   c. What does the grasshopper do to get ready for another jump?
   d. What movement throws the insect into the air? Is this movement made slowly or quickly?
   e. In what respects are the hind legs better fitted for jumping than are the two other pairs?
   f. What seems to be the use of the smaller pairs of legs when the insect lands on plants?
6. Move the outer wings sideways and forwards at right angles to the body so as to expose the under pair. Spread out or unfold the under wings. (It is an advantage to mount the specimens on cork and pin the wings in the position named above.)
   a. Which pair of wings is better fitted for flying? Why?
   b. How are the outer wings fitted to protect the under wings?
   c. (Optional.) Draw (× 2) the outline of a front wing and of a hind wing, and sketch in the principal veins. Label front wing, hind wing, veins.

D. *Organs of the abdomen; breathing.*

1. You will observe that each of the rings or segments of the abdomen is composed of an upper or *dorsal* half and an under or *ventral* half. Make a sketch (× 4) of a side view of four or five segments of the abdomen to show the structures mentioned above.

2. Secure an active grasshopper, put it in a live cage, and watch the movements of the upper and lower halves of the abdominal segments. Describe what you have observed.
3. In each segment, except those at the tip of the abdomen, there are two *breathing pores* or *spiracles*, one on each side. With the aid of a magnifier look for these breathing pores near the lower margin of the dorsal half of each segment. When you have found the spiracles in four or five segments, show them in your sketch (1, above), and label breathing pores or spiracles.
4. The spiracles lead into tiny elastic *breathing tubes* or *tracheæ* (singular *trachea*) which extend throughout all parts of the body of the insect even into the wings. The veins that you can see in the wings contain these minute tubes. Describe the tracheæ and state their extent and their connection with the spiracles (Fig. 17).
5. The tracheæ have an elastic material in their walls, so that when they have been compressed, they will spring back to their former shape and size as soon as the pressure is removed. Describe, now, the structure of one of the air tubes, and state what action this structure makes possible.

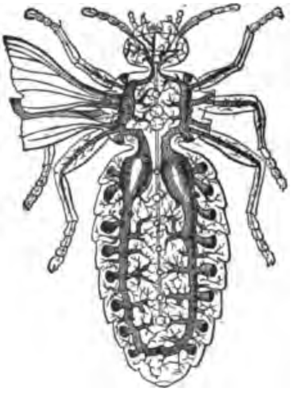

FIG. 17. — Air tubes (tracheæ) of an insect.

6. When the under or ventral half of the abdomen moves up into the dorsal half —
   a. Will the diameter of the abdomen be increased or decreased?

   b. Will the air tubes be made larger or smaller? Why?
   c. Will the air now rush into the air tubes or out of them? Why?

7. If the upper and lower halves of the abdomen now move apart —
   a. Will the diameter of the abdomen be increased or decreased?
   b. How will this movement affect the size of the tracheæ? Why?
   c. Will the air now move into the tracheæ or out through the spiracles? Why?

21. Characteristics of grasshoppers. — After studying two or three insects, the student will see that they all resemble the grasshopper (1) in having three regions of the body (head, thorax, and abdomen), (2) in possessing as appendages one pair of antennæ, one pair of compound eyes, two pairs of wings, and three pairs of legs, and (3) in having an abdomen made up of a number of rings or segments. The most distinguishing characteristics of the grasshopper and its relatives are found in its mouth parts and wings. Grasshoppers have biting mouth parts throughout their life. These consist of (1) an upper lip that is notched, (2) a pair of horny jaws, or *mandibles,* (3) a pair of rather complicated helping jaws or *maxillæ,* and (4) a lower lip. The two lips move up and down while the two pairs of jaws move from side to side. All these structures are well adapted for holding and biting off leaves of grass or other plants, and this seems to be the main business of this insect.

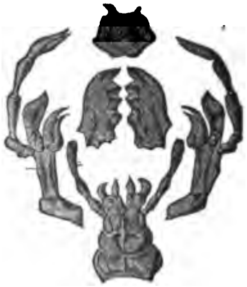

FIG. 18. — Mouth parts of a cockroach. (Parker and Haswell.)

Grasshoppers, too, are admirably provided with organs of locomotion. In fact, they derive their name from the extraordinary feats of jumping, which they accomplish largely by their long and muscular hind legs. If a boy could jump twenty times the length of his legs, that is, a distance of 50 feet, he would make an athletic record corresponding to that of the common red-legged locust. For the hind legs of an ordinary specimen of this insect are about 2 inches long, and they frequently leap 4 feet. The wings are also of great assistance in enabling the animal to secure its food or to escape its enemies. Flight is accomplished by the help of the hind pair only, and when these are not in use, they are folded like a fan beneath the outer pair.

22. Life history of the grasshopper. — The male grasshopper may be easily distinguished by the rounded tip of the abdomen; the abdomen of the female, on the other hand, has at its posterior extremity four movable parts which constitute the egg-laying organ or *ovipositor* (Fig. 19). The eggs are produced within the body of the female insect. Before these eggs can develop, however, each must be fertilized by a sperm-cell produced by the male grasshopper, just as an egg-cell of a plant must be fertilized by the sperm-nucleus of a pollen grain (**P. B., 91**). After the process of fertilization has taken place, the female grasshopper (usually in the fall of the year) burrows a hole in the ground by alternately bringing together, pushing into the earth, and then spreading apart, the four projections that make up the

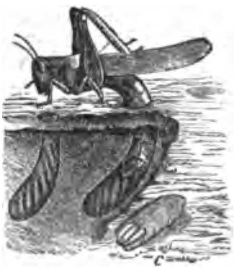

Fig. 19. — Grasshopper laying eggs. (Riley, U. S. Dept. of Agriculture.)

ovipositor (Fig. 19). From 20 to 40 small, banana-shaped eggs are then laid in the bottom of the hole. In the spring each egg hatches into a tiny grasshopper, which much resembles the adult, except that it has no wings and its head is relatively large in comparison with the rest of the animal. The insect begins at once to feed and grow, but since its whole exterior is hard and resistant, growth can only take place after this outer covering has been split and the insect has crawled out. This process is known as *molting,* and takes place five or six times during the life history of the animal. The insect then forms a new and larger coat. At each molt the wings become more fully developed, until at the last molt the adult insect is produced (Fig. 20). Hence, in the life history of the grasshopper there are three more or less distinct stages: (1) the egg, (2) the developing insect, which is known as the *nymph,* and (3) the adult grasshopper. This succession of changes in a life history is known as *metamorphosis* (Greek, *meta* = one after another + *morphos* = form). But, because in the development of the grasshopper these changes are not so striking as those that occur in the life history of the butterfly (11), the metamorphosis of the grasshopper is said to be *incomplete.* It is better, however, to refer to it as a *direct metamorphosis,* that of the butterfly being known as an *indirect metamorphosis.* After reaching the adult stage and depositing eggs, the adult insects die. Only a few of the immature grasshoppers survive the winter, and these are the grasshoppers that are seen early in Spring.

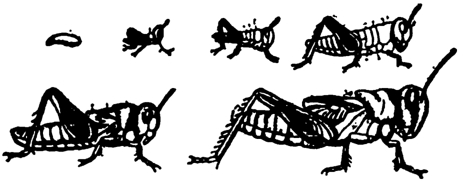
FIG. 20.—Stages in life history of a grasshopper.

23. Economic importance of grasshoppers. — Our laboratory study of a grasshopper's mouth parts and our observations of its methods of feeding have shown that these insects resemble caterpillars, first, in having biting mouth parts (Fig. 18), and second, in being voracious eaters. Hence, as we should expect, a large number of grasshoppers in a given area would mean a considerable destruction of plant life. Many " plagues of locusts " (for grasshoppers are more correctly known as locusts) have been recorded in history. One of the first is that recorded in the Bible, which occurred before the departure or " Exodus " of the Children of Israel from Egypt. " And they (the locusts) did eat of every herb of the land, and all the fruit of the trees . . . and there remained not any green thing in the trees, or in the herbs of the field throughout all the land of Egypt." (Ex. x. 15.)

In our own country during the years 1866 to 1876 there were several plagues of locusts in the grain-producing states of the West, notably in Kansas and Nebraska. The Rocky Mountain grasshoppers during these years migrated in such numbers that the sky was darkened during their flight, and the result of their devastation was as serious as that described in Exodus. According to one authority this species of insect destroyed $200,000,000 of crops in the western states in the space of four years. No great migrations have occurred since 1876.

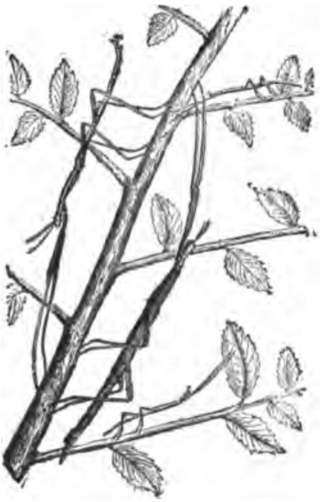

FIG. 21. — Four walking sticks on a branch. (Coleman.)

Locusts have been used as food, and even at the present day they are commonly eaten by the Arabians. In the Bible, it is related of John the Baptist, that while preaching in the wilderness " he did eat of locusts and wild honey."

24. Relatives of the grasshopper. — Other insects that have structure, habits, and life history similar to those of the grasshopper are the crickets, cockroaches, katydids, and walking sticks.

The cockroaches are more commonly known in New York City as "Croton bugs" from the fact that they frequent places close to water pipes through which Croton water is carried. They are very fast runners, as any one knows who has tried to catch them, and their bodies are so thin that they can easily hide away in narrow cracks. Their sharp jaws enable them to feed upon dried bread and other hard food (Fig. 18).

Katydids and walking sticks are striking examples of *protective resemblance;* that is, they resemble their surroundings in form or color so closely that they may secure protection from their enemies by this means (Fig. 21).

III. BEES AND THEIR RELATIVES

25. A study of the bumblebee. — (Laboratory study.)

A. General survey.

1. Give the names of the regions that you find in the body of the bee. (See **20**, *A*.)
2. State the number and situation of the antennæ. (See **20**, *B*.)
3. How many compound eyes are present, and where are they situated? (See **20**, *B*, 3.)

4. (Optional.) With the help of a magnifier look for the simple eyes on the top of the head and between the compound eyes. How many simple eyes are there, and what is their color? (See **20**, *B*, 4.)

5. Examine the legs and state —
    a. Their number, and the region of the body to which they are attached.
    b. The relative size of the different pairs.
    c. Their adaptations (by structure) for walking.

6. Examine the wings and state —
   - *a.* Their number, and the region of the body to which they are attached.
   - *b.* Their characteristics of texture.
   - *c.* Their adaptations for flying.
7. Is the abdomen segmented or not?

B. Food-getting organs.

1. If the mouth parts do not project from the lower part of the head, you should find them bent backward beneath the head and thorax. Use the dissecting needle to straighten them out. Carefully separate these mouth parts and count them.
   - *a.* How many mouth parts do you find?
   - *b.* Describe the general shape of all these parts.
   - *c.* How are the mouth parts fitted to enable the bee to get nectar from flowers?

2. (Optional.) Spread the mouth parts on some white blotting paper and stick pins into the blotting paper so as to keep the parts from coming together. Use the magnifier to distinguish the following parts: —
   - *a.* The central, longest part, the *tongue.* (It has hairs on its surface.) The tongue springs from a broader body, the *lower lip.*
   - *b.* Two shorter parts on either side of the tongue, springing also from the lower lip, and called *labial palps* because they are believed to correspond to the jointed bodies of that name attached to the lower lip of the grasshopper and other insects. (See **20**, *B*, 7.)
   - *c.* Two broader parts springing from a point farther back than the labial palps and supposed to correspond to the helping jaws of the grasshopper, and hence called *maxillæ.* (See **20**, *B*, 8.)

   Draw a front view of the outline of the head and of these five mouth parts (× 4). Label each part.

3. (Optional.) The bee also has a pair of small *mandibles.* They are attached to the head below the compound eyes. They extend forward and are often crossed underneath the lower lip. Separate them carefully with the dissecting needle. When the bee uses them, it bends the other mouth parts back out of the way.
   a. Are the mandibles hard or soft?
   b. Describe their color and shape.
   Note. — The honeybee uses the mandibles in forming the wax cells of the comb, and also at times as organs of defense.

4. Examine the hind leg and find the following parts: —
   a. A fairly prominent segment nearest the thorax, the *femur;*
   b. A segment larger than the femur and just below it, the *tibia;*
   c. A broad segment below the tibia, the proximal part of the foot or *tarsus;*
   d. The remainder of the tarsus or foot consisting of four tiny segments with two hooks on the end segment.
   Make a drawing of one of the hind legs (× 4) to show all these parts in outline and label femur, tibia, basal part of tarsus, hooks, tarsus.
5. Examine the outer surface of the tibia with a magnifier, noticing several rows of hairs around the margin. The portion of the tibia that faces outward, together with the hairs, is called the *pollen basket.*
   Locate the pollen basket and show how it is adapted for holding pollen.

26. History of beekeeping. — "It is abundantly evident from the records of the remote past that beekeeping has always been a favorite occupation with civilized nations. Egypt, Babylon, Assyria, Palestine, Greece, Rome, and Carthage all had their beekeepers. . . . In the days of Aristotle (in Greece) there are said to have existed two or three hundred treatises on bees, so that, then as now, beekeeping was a favorite topic with authors. More books have appeared on bees and bee-culture than have ever been published about any domestic animal, not excepting the horse or the dog."[1]

Yet from the earliest times until the middle of the last century there was little improvement in the method of keeping bees. They were allowed to build their combs in hollow trunks of trees or in hives so constructed that it was impossible to control in any way the work of the bees (Fig. 22). In 1852, however, Rev. Lorenzo Langstroth of Philadelphia invented a hive with movable frames, and his invention wholly revolutionized the beekeeping industry. Practically all modern hives throughout the world are constructed on the plan that he introduced, which is essentially as follows. In a rectangular box are suspended eight to ten movable frames, in each of which the bees build their comb, store honey, and develop their young; for this reason this part of the hive is known as the *brood chamber*. (One of these frames, covered with bees is shown in Fig. 23.) As the season advances, the beekeeper places above the brood chamber successive *supers* (Latin, *super* = above), each supplied with little boxes (Fig. 23) which when filled with honeycomb usually weigh about a pound. It is this excess of stored honey that is commonly offered for sale.

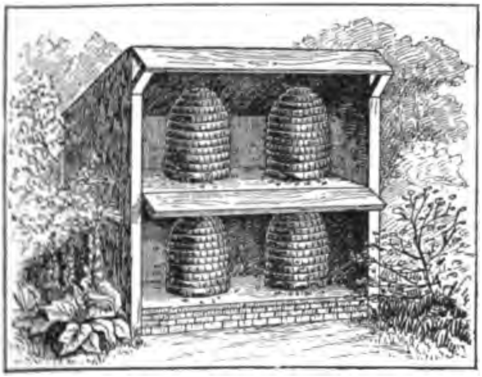

FIG. 22.—Old type of beehive. (From International Encyclopedia. Dodd, Mead & Co., N. Y.)

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[1] Cyclopedia of American Agriculture, Vol. III, p. 278.

27. Characteristics and functions of the queen and the drones. — Honeybees, though smaller than bumblebees, resemble them in their general plan of structure; that is, both kinds of insects have a head, thorax, and abdomen, all more or less covered with hair, and on the thorax are two pairs of membranous wings and three pairs of jointed legs. In every colony of bees there is, except at rare intervals, only one queen. The queen-bee (Fig. 24) can be readily distinguished from all the other individuals in the hive by her long, slender abdomen (Fig. 24). It is her sole busi-

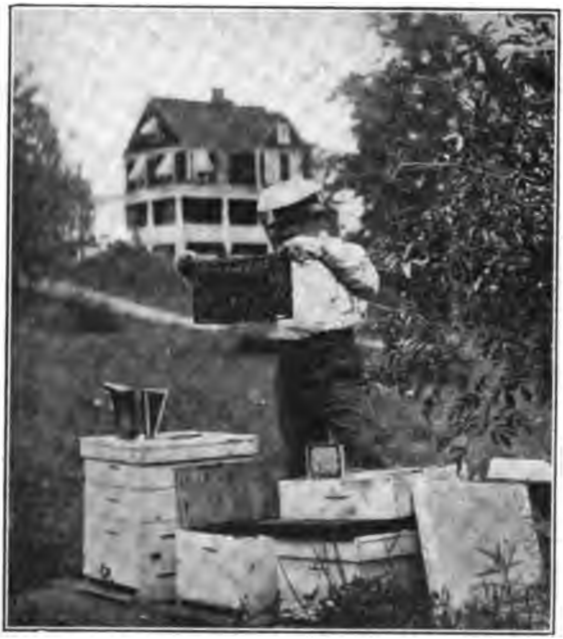

FIG. 23. — Modern type of beehive.

ness to deposit an egg in each of the various wax cells of the brood chamber. Queens have been known to lay 3000 eggs in a single day, and since a queen may live as long as five years, she may lay over 1,000,000 eggs during a lifetime. The queen is therefore the mother of all the bees in a colony.

The distinguishing characteristics of drone or male bees (Fig. 24) are their broad abdomens, the absence of a sting, and their very large, compound eyes, which nearly meet on the top of their heads. In numbers they vary at different times of the year, but during the summer there are usually 400 to 800 in a hive.

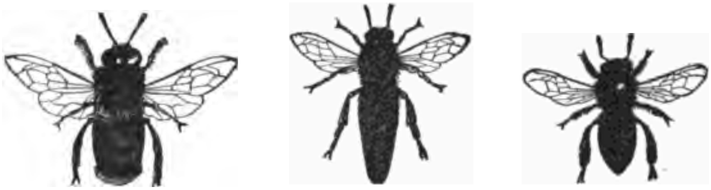

FIG. 24. — Drone, queen, and worker bee.

We learned in our study of reproduction in plants that egg-cells will not develop into seeds unless they are fertilized by sperm-cells of pollen grains. Now in a beehive, an egg will never develop into a queen-bee or a worker unless it likewise is fertilized by a sperm-cell. The drones or male bees supply these necessary sperm-cells. From the unfertilized eggs, which a queen may lay, develop only drone bees. In this respect these egg-cells of bees are strikingly different from those of plants and of most animals.

It is clear from the foregoing account that the queen and drones carry on the *reproductive functions* of the colony, for they are specially adapted to increase the number of bees in a hive. To the workers, on the other hand, as we shall now see, belong most of the *nutritive functions* of the colony.

28. Characteristics of worker bees. — While the workers are smaller than either the queen or the drones, they are by far the most numerous, there being as many as 50,000 in a good colony in midsummer. In shape they resemble the queen, as one would expect, since they are undeveloped female bees. As was the case with the bumblebee, their mouth parts are very complicated, consisting of a central tongue and two other pairs of appendages, all of which form a hollow tube for sucking up the nectar of flowers (Fig. 25). Above the tongue is a pair of horny jaws that move from side to side, which the bees use mainly for comb building. On the tibia of each hind leg of a worker bee is likewise a fringe of stiff hairs, which, together with the concave outer surface of the tibia, forms a pollen basket similar to that of the bumblebee. In this the insect gathers a mass of pollen which may easily be seen when the workers are returning to the hive (Fig. 26).

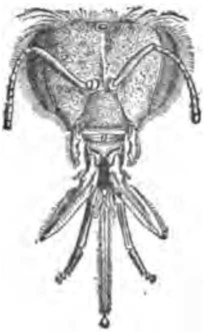

Fig. 25. — Mouth parts of a bee.

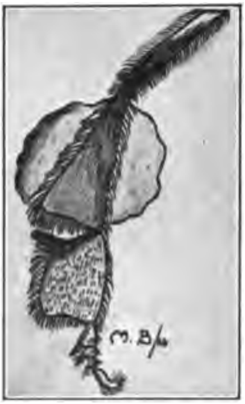

Fig. 26. — Hind leg of bee with pollen, inner surface.

29. Comb building. — All the work of comb manufacture is carried on by the worker bees, and when one studies this process carefully, it is found to be one of the greatest marvels of animal activity. The cells of the comb are built out horizontally from each side of a central partition in a brood frame or of a super box. To save the bees' time and to insure even comb, beekeepers usually insert in the frames or honey boxes thin sheets of wax "foundation" on which the bases of the cells have been impressed by machinery. Upon this the workers build the comb outward. But without this assistance from man the comb cells are usually remarkably regular and show the greatest economy in the use of wax. The cross section of each cell is a hexagon, and so these compartments fit together without any spaces between them as would occur if the cells were cylinders. (See Fig. 27.) This hexagonal shape also permits a single partition wall to serve for two adjacent cells, and it is evident that this shape of cell more closely fits the body of the bee than would a four-sided cell. The worker bees build two different sizes of cells in the comb. Most of the cells average about twenty-five to a square inch, and in these the fertilized eggs are laid, which, as we have said, develop into workers. The cells in which unfertilized eggs are deposited are somewhat larger. These form the so-called *drone comb.*

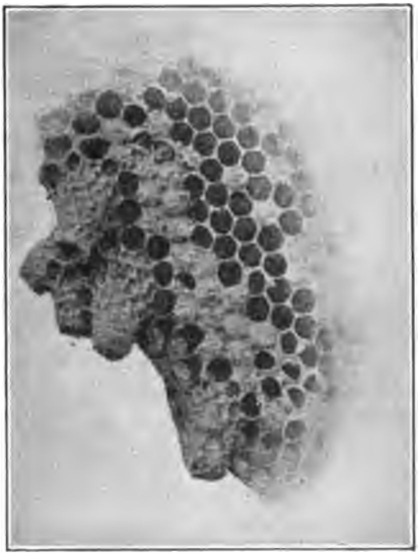

FIG. 27. — Worker cells and queen cells. (From "A, B, C of Bee Culture." A. I. and E. R. Root.)

The wax from which the comb is produced oozes out from certain glands on the ventral surface of the abdomen of the workers. When producing the wax the bees hang motionless inside the hive for several days, each holding to the bees above. They have already gorged themselves with honey, and it is estimated that from seven to fifteen pounds of honey are required to produce one pound of wax. As the little plates of wax are formed, they are seized by a bee and carried with its mandibles or under its " chin " to the comb where the building is going on. Here the wax is pressed against one of the walls.

30. Honey making. — While studying flowers we learned that they secrete a sweet liquid known as nectar. It is this that the workers use for honey manufacture. The bee inserts into the blossom its sucking tongue and pumps up the nectar into a sac known as the *honey stomach* (Fig. 28). Here a kind of digestion takes place whereby the nectar is changed to honey. If the worker bee is hungry, it opens a little trapdoor and allows the honey and pollen to pass into the true stomach. But since the insect usually makes more honey than it can use, when it returns to the hive it squeezes its tiny honey stomach and deposits the surplus in the cells of the comb. This honey, when first made, contains a good deal of water; it would therefore take up too much room in the comb and it would be more likely to run out from the horizontal cells. Hence, some of the workers fan with their wings and evaporate the surplus water. When the cells are completely filled, they are capped over with wax.

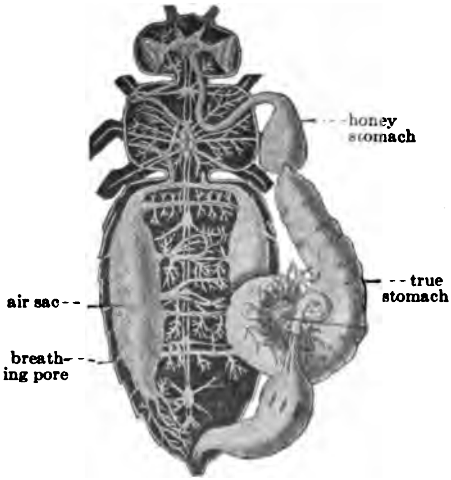

FIG. 28. — Internal organs of bee. (Lang.)

31. Other duties of worker bees. — Bees, we have also learned (**28**), bring in large quantities of pollen packed in the pollen baskets of the hind legs, and in gathering pollen a considerable amount clings to the head and other parts of the body. Worker bees also bring in from the buds of trees a brown, gummy substance called bee glue or *própolis* which they use to close up crevices in the inside of the hive. In most hives, too, certain bees seem to be detailed to act as soldiers to keep out individuals from another swarm or other marauders which might raid their stores of food. During the busy summer season a worker usually lives only a month or two.

Certainly enough has been said to convince any one that a bee colony is a wonderful social community, organized more completely, so far as division of labor is concerned, than many a human community. Is it a monarchy ruled by the queen, or a democracy controlled by the workers? The latter is more probably the case. Yet we can hardly imagine how the thousands of individuals can work together in such a helter-skelter way and accomplish such wondrous results.[1]

32. Life history of the honeybee. — The *eggs* of the bee are tiny white objects, shaped more or less like a banana. A single egg is fastened by the queen mother at the bottom of each cell in the brood comb (Fig. 29). At the end of three days the egg hatches into a minute footless *grub* or *larva* (Fig. 29) which is fed for the first few days on rich food, produced in the stomach of the

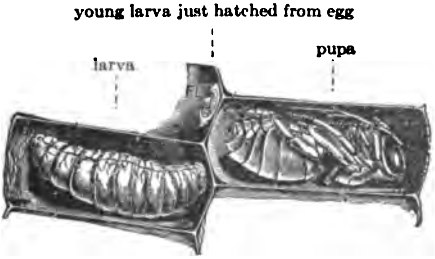
young larva just hatched from egg
larva
pupa

Fig. 29. — Stages in life history of honeybee. (Cheshire).

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[1] For interesting descriptions of the work carried on in a beehive see "A, B, C of Bee Culture," by A. I. and E. R. Root.

workers that are acting as nurses. The grubs are then fed with a mixture of pollen and honey, and at the end of six days after hatching they are supplied with enough of this mixture to last during the rest of the larva stage, and the cells are then capped over with wax by the workers. There the developing bees pass through the third or *pupa stage* (Fig. 29), and at the end of twelve days bite their way out of their nursery cells and take their share in the busy toil of the hive.

Drones, we have said, develop in somewhat larger cells than worker bees. When the colony wishes to produce a queen, the workers build a cell about as large as the end-joint of one's little finger (Fig. 27), and as soon as the egg is hatched they stuff the little grub throughout the larval stage with what is called " royal jelly," never giving it the undigested pollen mixture that is supplied to the grubs of workers or drones.

33. Swarming. — We come now to one of the most interesting events in the story of bee colonies. If several queens emerge from their cells at the same time, they attack each other in a royal battle, for it is said that a queen never uses her sting except against a rival. When the conflict is over, the victorious queen becomes the mother of the hive. For in the meantime the former queen, surrounded by half the drones and workers, has left the old hive, abdicating in her daughter's favor. After emerging from their old home, the swarm of bees thus formed alights on a neighboring tree, clinging to each other in a solid mass. It is then comparatively easy for a beekeeper to shake the insects from the limb into a new hive, and if the queen is secured, the swarm will usually begin work at once in their new home (Fig. 30). If, however, the bees are not captured, scouts go out to search for a hollow tree; and when satisfactory quarters are found, the whole swarm follows their guides, and build their comb in the home thus secured.

34. Economic importance of bees. — In our study of flowers we referred frequently to the necessity of the visits of bees to insure cross-pollination. Indeed, Professor Hodge says ("Nature Study and Life") that for all practical purposes so far as man is concerned, the honeybee is sufficient for this purpose (with the exception of securing a red clover crop, which requires the help of the bumblebee). The most successful fruit farmers keep bees in order to secure cross-pollination, which insures a larger fruit crop.

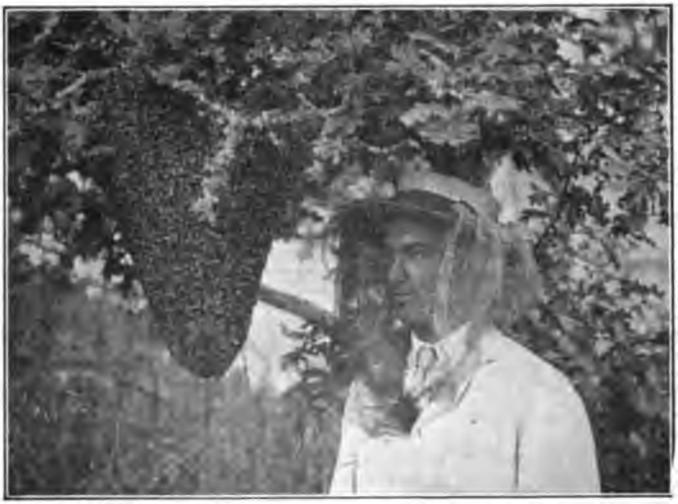

FIG. 30. — A swarm of bees on a limb. (Lyons.)

It is estimated that the annual production of honey and wax in the United States amounts to between twenty and thirty millions of dollars, and if scientific management were to be introduced more widely, this output could be raised to fifty million dollars a year without additional investment. Almost any one who is interested can keep bees. During a single season the swarm in the observation hive on the fourth floor of the Morris High School in New York City produced fifty-six pounds of honey in the super boxes, besides laying by in the brood chamber a sufficient supply for their winter support.

35. Relatives of the bees. — Wasps and hornets belong to the same order of insects as the bees, and resemble them more or less closely in structure. Some kinds of wasps build paper comb from wood which they chew up with their jaws. Ants, insects with which every one is familiar, are likewise classed with the bees and wasps, and the social communities that they form are marvelous in the degree to which they carry division of labor. In some ant colonies in addition to the workers there are soldiers and slaves.

IV. MOSQUITOES AND FLIES

36. Life history of the common inland or house mosquito. — The eggs of the common house mosquito are laid by the female in little rafts that float on the surface of stagnant water. These egg masses look like flecks of black soot, but when examined with a hand lens each is found to consist of 200 to 400 cartridge-shaped eggs standing on end (Fig. 31). If the weather is warm and other conditions are favorable, the eggs hatch within a day into tiny mosquito larvæ, which are known as "wrigglers" from their characteristic motion in the water.

In the second stage in its life history, which usually lasts about a week, the mosquito larva feeds on the microscopic plants and animals that abound in all stagnant water, and grows rapidly. Just as was the case with the butterfly and moth caterpillars, this rapid growth necessitates the frequent shedding or *molting* of the outer covering of the larva and the formation of a new and larger coat. Hence, in water

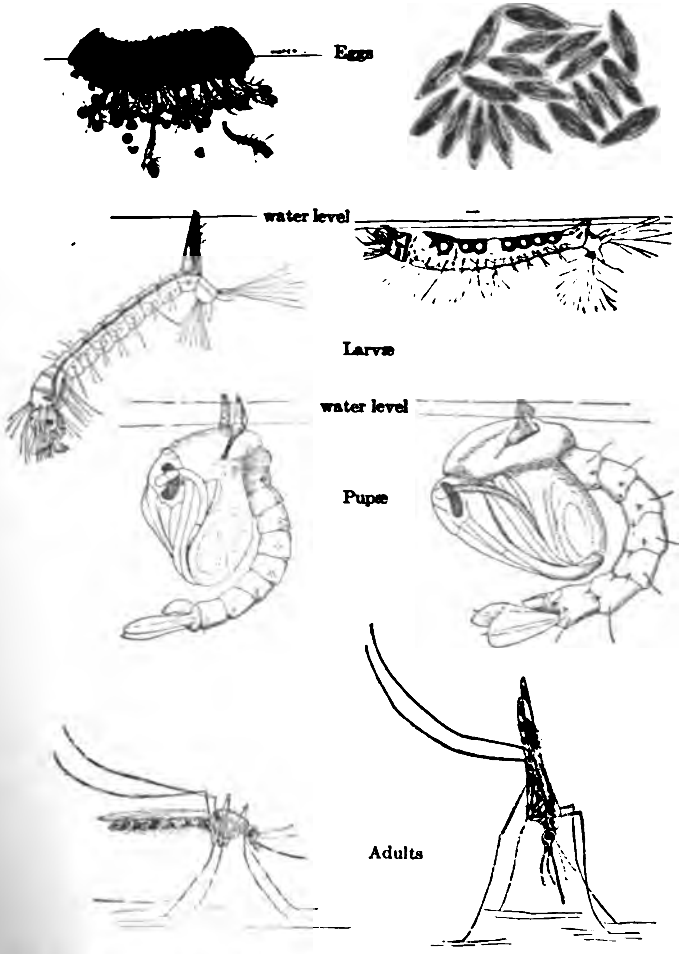

FIG. 31. — Life history of house mosquito (Culex).

FIG. 32. — Life history of malaria mosquito (Anopheles).

(Howard, U. S. Dept. of Agriculture.)

where mosquitoes breed, one finds countless " suits of cast-off clothing " which would fit all stages of the young wrigglers.

The mosquito larva has a well-developed head, a thorax, and a jointed or *segmented* abdomen, but legs and wings are wanting. The most striking characteristic of this stage of the mosquito is the breathing tube that projects diagonally from the hind end of the abdomen. For while the mosquito larva lives in the water, it is obliged to swim to the surface at short intervals to get its necessary supply of air. It then hangs diagonally with the tip of its breathing tube projecting through the surface film into the air above (Fig. 31). This habit frequently proves its undoing, as we shall see when we come to discuss the methods of mosquito extermination.

After attaining its full growth as a larva, the insect enters the third or pupa stage (Fig. 31). " The pupa," says Miss Mitchell in her " Mosquito Life," " is the form intermediate between the larva and the adult. Unlike most pupæ, those of the mosquito are very active, but like other pupæ, they do not eat. They are about the shape of fat commas, floating quietly at the surface or bobbing crazily downward at the least alarm to hide at the bottom, propelled by backward flips of the abdomen. . . . The creature no longer breathes through a single tube on the eighth segment of the abdomen but by means of a pair of tubes on the back of the thorax." During this stage the insect develops its sucking mouth parts, its long, slender legs, and its two delicate wings, and all these organs may be seen through the transparent outer coat, which is composed of a substance known as *chitin.*

At the final molt the mosquito leaves its pupal case in the water and flies into the air, an adult mosquito. If it hatches during the spring, summer, or early autumn, it usually lives no more than a week or two; but many of the female mosquitoes that develop late in the autumn seek out a protected spot in which to spend the winter, and thus are ready in the spring to perpetuate the species by laying eggs in the stagnant pools formed by early rains.

All that the mosquito needs, therefore, in order to develop its offspring from egg to adult stage is a bit of water that will remain relatively undisturbed for about two weeks. Hence, old tomato cans, bits of crockery, and other receptacles carelessly left in many a back yard, furnish breeding places for all kinds of mosquitoes.

Truth compels us to remark, in passing, that the male mosquito is a decent sort of fellow, keeping close to his breeding place and feeding on plant juices or eating nothing at all during his brief existence in the adult stage. It is the lady mosquito that torments us by singing her piercing song and piercing our suffering skins. But as in most other sufferings that we endure, the fault is largely our own. At least we can secure immunity if as communities we but persist in applying the simple methods of extermination outlined in **42**.

37. Life history of malaria-transmitting mosquitoes.— The mosquito we have just described, while a nuisance wherever found, does not, so far as is known, cause disease. There are, however, two kinds of mosquitoes that are not only a nuisance but a menace to life and health wherever they are found; namely, those that transmit malaria and yellow fever. The first of these is the *Anópheles* mosquito, commonly known as the "malaria mosquito," for as we shall soon see, malaria cannot be transmitted from one human being to another except through the agency of this species of insect. The eggs of the Anopheles mosquito are larger than those of the house mosquito and are laid singly, not in masses (Fig. 32). In the larva stage, likewise, the two insects may be easily distinguished from the fact that the "malaria wriggler," while breathing, lies horizontally just beneath the surface of the water, while the other species hangs downward, with only the tip of the breathing tube projecting to the water level (Figs. 31 and 32).

In Figs. 31 and 32 the characteristic position of the adults of the two species is shown. While the body of the house mosquito is usually parallel to the surface on which it alights, that of the malaria-transmitting insect is sharply tilted away from the surface.

38. Occurrence and cause of malaria. — The story of the discovery that a kind of mosquito known as the Anopheles mosquito is the only means, as far as we now know, by which malaria may be transmitted from one individual to another, is one of the most wonderful in all the history of biology. In a guide leaflet on "The Malaria Mosquito" published by the American Museum of Natural History, New York City,[1] the author, B. E. Dahlgren, writes as follows: —

"It was early observed that 'malaria' was apt to be prevalent during the damp and rainy seasons, and that it occurred principally in exactly such places as are now known to furnish ideal breeding grounds for the malaria mosquito. That new cases of malaria appeared at the time of year when the Malaria Mosquito abounded, was also recorded long before it was suspected that the insect was in any way connected with the malady; and one of the old medical writers mentions as a characteristic of malaria seasons that 'gnats and flies are apt to be abundant.' . . .

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[1] Every one who visits the American Museum should study carefully the wonderful set of models that show on a big scale the various stages in the life history of the mosquito. These models are pictured in the bulletin referred to above, which may be obtained from the librarian of the Museum for fifteen cents.

"Malaria was formerly considered to be a form of ague due to foul air, whence its name, which literally means 'bad air.' It was attributed to a sort of 'miasma.' Its true nature did not become known till 1880, when Laveran, a French military surgeon, working, at the time, in Algeria, discovered the malarial parasite in human blood." Major Ross, an English officer in India, later proved the presence of the parasite in the body of the mosquito.

39. Transmission of malaria. — Investigation has shown that the parts of the world where Anopheles abound are the eastern half of the United States and a large part of Europe, together with many regions of the tropics. It is a well-known fact that these are the regions, too, in which malaria is very abundant, and this is the first line of proof that the Anopheles mosquito is always responsible for the transmission of malaria.

Even more conclusive were the experiments of four investigators who spent the fever season in the dreaded malaria district of the Roman Campagna. They built for themselves a carefully screened house in which they remained from sunset to sunrise, and this was the only precaution that they observed. In the daytime they went freely among those who were stricken with the fever, they allowed themselves to be soaked with the falling rains, and at night the air from the swamps came freely into their sleeping quarters. But while hundreds of malaria cases were all about them, not one of the four contracted the disease. Hence, to escape malaria, one has only to make sure that Mrs. Anopheles is prevented from injecting her billful of malaria germs — and this she does only during night time, " loving darkness, rather than light, because her deeds are evil."

In the year 1890 Dr. Manson and Dr. Warren, two physicians in London, allowed themselves to be bitten by Anopheles mosquitoes that had previously bitten malaria patients in Italy. In eighteen days both developed malarial fever and in the blood of both, malaria organisms were found, although previous to this infection from the mosquito neither had suffered in any way from the disease.

40. Life history of the malaria parasite. — But yet more wonderful proof that the mosquito transmits malaria has been furnished by the microscopes of biologists. The discovery of the malarial parasite by Laveran in 1880 has already been referred to. This resembles in its form and activities a single-celled animal known as the Amœba (**124**). When this organism of malaria is present in human blood, it bores its way into a red corpuscle (**H. B., 6**), feeds upon the contents of this blood cell, and grows at the expense of the corpuscle until the parasite occupies nearly all the space inside it (Fig. 33). The malaria parasite then divides into a number (6–16) of daughter parasites, which rupture the red corpuscle in which they have been developing, and escape into the liquid part of the blood, thus causing the chills so characteristic of malaria. Each new parasite then attacks a new corpuscle and at the end of two or three days produces six to sixteen new spores, and so the organisms multiply.

Now here comes the relation of the mosquito to malaria. For when the female Anopheles bites a person having malaria, she is likely to suck up blood that contains malaria organisms in a certain stage of development. These reach the insect's stomach, where they pass through a stage known as fertilization. In the stomach of a single mosquito as many as five hundred of these fertilized cells have been counted. Each cell then becomes pointed at one end, bores its way through the wall of the mosquito's stomach, and in fifteen to twenty days produces relatively large swellings on the outer surface, in which are thousands of needle-shaped malaria spores (Fig. 33).

At length these spores escape through the outer wall of the mosquito's stomach and many of them find their way to the salivary glands. And so when the infected mosquito bites another person, these parasites are injected with the saliva, and if the conditions are favorable in the blood of the new victim, the spores straightway attack the red corpuscles, and a new case of malaria is the result.

For the treatment of malaria quinine is the most effective drug known at present. It should be taken in the quantity and at the times prescribed by the physician.

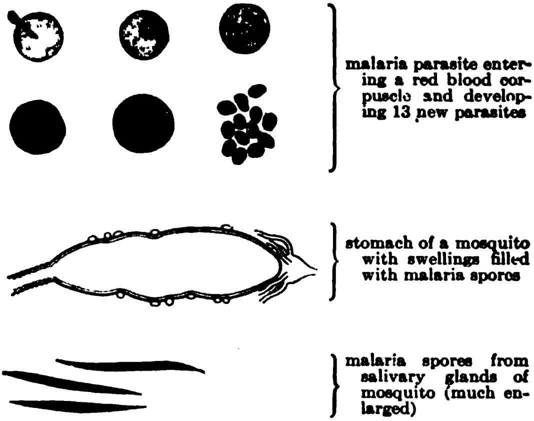
malaria parasite entering a red blood corpuscle and developing 13 new parasites
stomach of a mosquito with swellings filled with malaria spores
malaria spores from salivary glands of mosquito (much enlarged)

Fig. 33. — Life history of the malaria parasite. (Dahlgren, American Museum Natural History.)

41. Transmission of yellow fever. — The proof that malaria can only be transmitted from one human being to another was largely the work of the biologists of England, France, and Italy. The discovery that another kind of mosquito (*Stegomyia*) is responsible for the transmission of the parasite that causes yellow fever is due almost wholly to the splendid achievements of the Yellow Fever Commission appointed by President McKinley. In June, 1900, this commission of five, headed by Dr. Walter Reed (Fig. 34), began its epoch-making experiments in the Island of Cuba, and within six months these men demonstrated conclusively that this plague disease of the tropics and of our southern states can, so far as we know, be communicated only through the agency of the Stegomyia mosquito.

This commission, believing in the mosquito theory, at once began experiments to demonstrate its truth. One of the members, Dr. Lazear (Fig. 35), permitted a mosquito to bite him; a few days later he contracted the disease and died. The inscription on a tablet erected in his memory reads as follows: "With more than the courage and devotion of the soldier, he risked and lost his life to

FIG. 34.—Dr. Walter Reed.

show how a fearful pestilence is communicated and how its ravages may be prevented."

When Dr. Reed called for volunteers from among the soldiers, the first to respond "was a young private from Ohio, named John R. Kissinger (Fig. 36), who volunteered for the service, to use his own words, 'solely in the interest of humanity and the cause of science.' When it became known among the troops that subjects were needed for experimental purposes, Kissinger, in company with another young private named John J. Moran, also from Ohio, volunteered their services. Dr. Reed talked the matter over with them, ex-

FIG. 35. — Dr. Jesse Lazear.

plaining fully the danger and suffering involved in the experiment should it be successful, and then, seeing they were determined, he stated that a definite money compensation would be made them. Both young men declined to accept it, making it, indeed, their sole stipulation that they should receive no pecuniary reward, whereupon Major Reed touched his cap, saying respectfully, 'Gentlemen, I salute you.' Reed's own words in his published account of the experiment on Kissinger are: 'In my opinion this exhibition of moral courage has never been surpassed in the annals of the Army of the United States.'"[1]

FIG. 36. — John R. Kissinger, U.S.A.

The object of one of the first experiments was to determine whether or not yellow fever could be contracted from clothing worn by yellow fever patients. A small building was constructed the windows and doors of which were carefully screened. Into this were brought chests of clothing that had been taken from the beds of patients who had been sick and in some cases had died of yellow fever. Three brave men entered the building, unpacked the boxes, and for twenty nights slept in close contact with the soiled clothing. "To pass twenty nights in a small, ill-ventilated room, with a temperature over ninety, in close contact with the most loathsome articles of dress and furniture, in an atmosphere fetid from their presence, is an act of heroism which ought to command our highest admiration and our lasting gratitude."[2] In spite, however, of their unwholesome surroundings, none of the men contracted yellow fever, and so it was proved for all time that this disease cannot be communicated by means of anything that comes from the body of yellow fever patients.

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[1] From "Walter Reed and Yellow Fever," by Dr. H. A. Kelly Doubleday, Page & Co.

[2] "Walter Reed and Yellow Fever."

Dr. Reed now sought to prove that the *Stegomyia* mosquito was the means by which the disease was transmitted from one person to another. A second building, the same size as the first, was erected, the room was divided by a wire screen, and all the doors and windows were carefully screened (Fig. 37). Into one of the rooms a number of mosquitoes that had bitten yellow fever patients were freed and a few minutes later John Moran, an Ohio soldier, entered and allowed these mosquitoes to bite him. "On Christmas morning (1900) at 11 A.M. this brave lad was stricken with yellow fever and had a sharp attack which he bore without a murmur." On the other side of the screen were three soldiers who were protected from mosquitoes; and these men remained in perfect health. This experiment proved conclusively that yellow fever is transmitted by the Stegomyia mosquito.

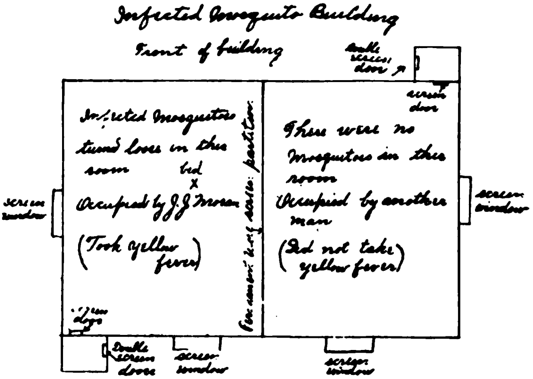

FIG. 37. — Plan of infected mosquito building. (Drawn for the authors by John R. Kissinger.)

42. Extermination of mosquitoes. — Now all the suffering from malaria and yellow fever is entirely unnecessary if communities will but take the trouble to eradicate all breeding places of mosquitoes. Since the mosquito, during its development in the water, comes frequently to the surface to secure air for breathing, a thin film of oil spread over the surface of the water in which they are breeding is a sure means of killing them. But the kerosene treatment is at best but a temporary means of ridding a community of mosquitoes. The oil has to be renewed every two or three weeks, especially after rains, to make sure that a continuous film covers the surface. Hence, wherever possible, pools should be drained, and one has but to read Dr. Doty's account of his marvelous success in abating the mosquito nuisance on Staten Island (see New York State Journal of Medicine, May, 1908) to be convinced that this method is effective (Figs. 38 and 39). Every householder should coöperate by

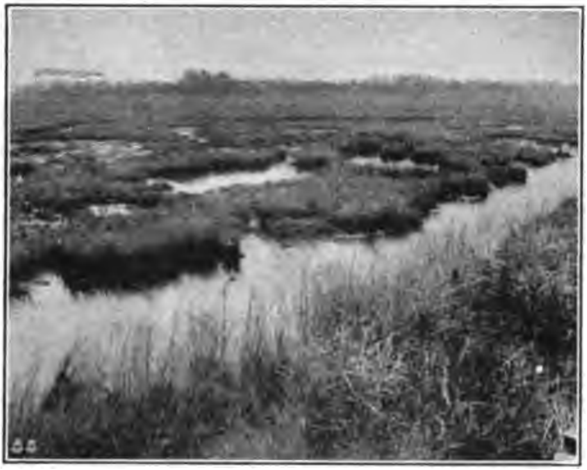

Fig. 38.—Staten Island marshes before drainage.

cleaning up his own back yard and by covering cisterns and wells with the finest meshed netting; for the insistent mosquito has been known to make its way through ordinary wire netting. Fish and dragon flies are also important helps to man, since these animals devour great numbers of larvæ, pupæ, and adult insects; yet at best they can hardly be counted as efficient means of ridding swamps of mosquito pests.

Anopheles, Culex, and Stegomyia lay their eggs in the same kind of stagnant pools, and the proper filling, draining, or screening of these pools or their treatment with kerosene, will destroy the one as well as the other. When this is accomplished, malaria and yellow fever, as has been conclusively demonstrated by the work of Americans on Staten Island, New Orleans, Cuba, and Panama, will practically disappear.

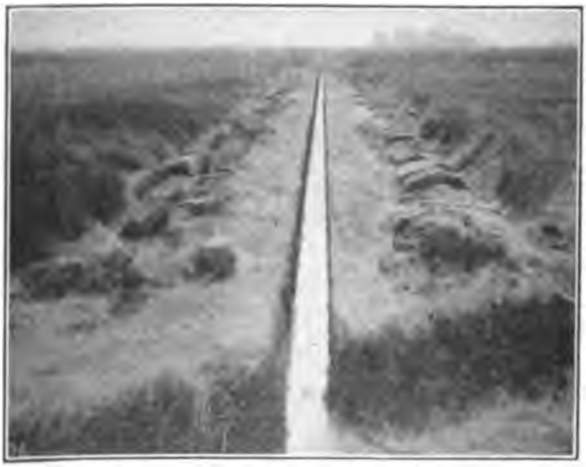

FIG. 39.—Staten Island marshes after drainage.

43. Habits and life history of the house fly. — It has been clearly proved that the common house fly is a frequent cause of disease; especially is this true in the transmission of typhoid fever and the intestinal diseases to which the deaths of so many young children are due. Practically all parts of the body of a fly are covered with hairs (Fig. 41), especially the mouth parts and feet. Each foot, also, has sticky pads (Fig. 40) which enable the fly to cling to the walls and ceilings. In the adult stage the flies feed upon filth of all sorts, and if they alight on the excretions of typhoid patients, they are very likely to carry on their feet and mouth parts the germs of the disease, and so when they come into the house, they may infect milk and other food. Flies also carry germs of other diseases such as cholera, dysentery, and tuberculosis.

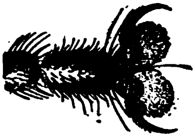
FIG. 40. — Foot of fly, showing hairs and pads.

The most common breeding place of house flies is in piles of horse manure. Here the female fly lays about 120 eggs (Fig. 41) which hatch within a few hours into tiny white footless grubs. These feed for about five days upon the manure and grow rapidly, molting twice within that time. The larva now changes into a pupa, and at the end of another five days the adult fly emerges from the brown pupa case. Egg laying begins almost at once, and as each adult female fly lays 120 eggs, it has been estimated that a single fly may have 5,598,720,000 descendants in a single season if each fly were to deposit but one batch of eggs. In reality, however, a fly deposits four batches in a season. Hence it is very important to catch and kill flies at the very beginning of each season.

44. Extermination of house fly. — Because of the danger of disease transmission every housekeeper should do her best to screen her house and so keep flies away from food, for one never knows where these insects have been crawling or what disease germs may be clinging to their feet. City authorities should see that all street refuse and garbage are removed before flies of any kind can lay their eggs therein. All persons

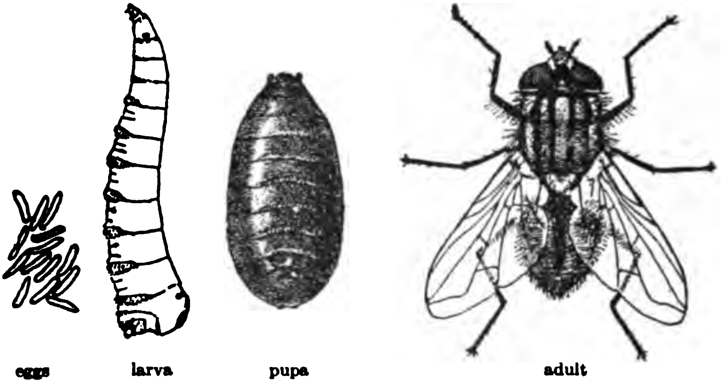

FIG. 41. — Life history of house fly.

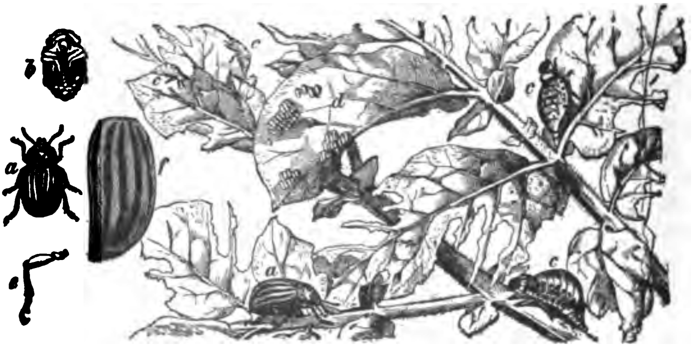

FIG. 42. — Life history of potato beetle. Identify eggs, larvæ, pupa and adult.

responsible for horse stables should make sure that the manure is thrown into screened pits and sprinkled with chloride of lime at least once a week.

Another method of dealing with the problem is that suggested by Professor C.F. Hodge of Clark University, Worcester, Mass. It is that of letting the flies catch themselves. He has devised a simple and inexpensive flytrap, which is easily attached to any garbage can (or to a window screen); or it may be baited with bits of fish or other food. The flies are attracted by the odors of the garbage or food bait, and when caught may be killed with boiling water. If the various suggestions are followed, even farmhouses, as experience has shown, may be rendered practically free from the filthy and dangerous house fly.

V. Additional Topics on Insects

45. Field and library study of other insects. — (Optional.) Study as many of the following insects as time allows, consulting Sanderson's "Insect Pests of Farm, Garden, and Orchard," Hodge's "Nature Study and Life," National and State Circulars and Bulletins, articles in Encyclopedias or other reference books. Emphasize especially the habits, life history, and economic importance of each of the following insects: Colorado potato beetle (Fig. 42), cut worms, army worms, San José scale (Fig.43), tent caterpillar, chinch

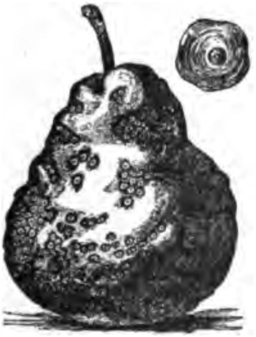

Fig. 43. — San José scale insects on pear. Above, single scale enlarged. (Howard.)

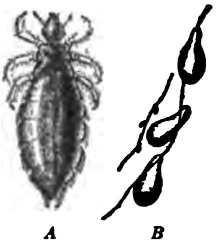

Fig. 44. — *A*, human louse; *B*, eggs attached to hair.

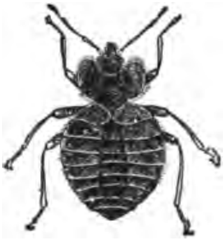

Fig. 45.—Bedbug.

bug, cockroaches, plant lice, human lice (Fig. 44), bedbugs (Fig. 45), carpet beetles, lady bugs, scavenger beetles, ichneumon fly.

46. Annual loss due to insect pests of the United States.[1] — "In no country in the world do insects impose a heavier tax on farm products than in the United States. The losses resulting from the depredations of insects on all the plant products of the soil, both in their growing and in their stored state, together with depredations on live stock, exceed the entire expenditures of the national government, including the pension roll and the maintenance of the army and the navy." This loss for the year 1904 was estimated at $795,100,000, and this does not include the expense involved in applying insecticides.

Product	Value	Percentage of Loss	Amount of Loss
Cereals	$2,000,000,000	10	$200,000,000
Hay	530,000,000	10	53,000,000
Cotton	600,000,000	10	60,000,000
Tobacco	53,000,000	10	5,300,000
Truck crops	265,000,000	20	53,000,000
Sugar	50,000,000	10	5,000,000
Fruits	135,000,000	20	27,000,000
Farm forests	110,000,000	10	11,000,000
Miscellaneous crops	58,000,000	10	5,800,000
Animal products	1,750,000,000	10	175,000,000
Total	$5,551,000,000		$595,100,000
Natural forests and forest products			100,000,000
Products in storage			100,000,000
Grand total			$795,100,000

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[1] C. L. Marlitt in Year Book of United States Department of Agriculture, 1904. The figures are regarded as conservative estimates.

47. Insecticides.[1] — In our laboratory studies we have found that there are two kinds of insects, namely those with biting mouth parts and those with sucking mouth parts. Entirely different treatment is necessary in dealing with insect pests of these two types. Insects with biting mouth parts may usually be killed by thoroughly spraying the parts of a plant upon which they feed with a mixture made in the following proportions: —

	1 GAL. MIXTURE	50 GAL. MIXTURE
Arsenate of lead (poison) . .	⅘ oz. (1 teaspoonful)	2½ lb.
Water	1 gal.	50 gal.

Insects with sucking mouth parts, on the other hand, must be treated with a spraying mixture which will actually touch their bodies. Some of the "contact insecticides" for this purpose are whale oil soap (one pound to five gallons of water), kerosene emulsion, and "black-leaf-40." The last named is preferable for killing plant lice and it is mixed with soap as follows: —

	1 GAL. MIXTURE	50 GAL. MIXTURE
Black-leaf-40 (40 per cent nicotine)	⅙ oz. (= 1 spoonful)	½ lb.
Ivory or laundry soap . . .	⅝ oz. (size of two yeast cakes)	2 lb.
Water	1 gal.	50 gal.

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[1] The authors are indebted to Professor Glenn W. Herrick of Cornell University for these formulas.

CHAPTER II

BIRDS

48. Study of a bird. — (Optional home work.)

So far as possible the following study should be made from a robin, sparrow, chicken, or other living bird, and the observations should be supplemented by an examination of stuffed specimens, charts, or pictures.

A. *Regions.*

In all animals that have internal bony skeletons as do birds, at least two of the following regions may be distinguished; namely, a head, a neck, a trunk, and a tail.

Which of the four regions named above can you distinguish in the bird that you are studying?

B. *Head.*

1. Describe the general shape of the *beak* (or *bill*), stating whether it is relatively long and slender, or short and thick. State, also, whether the tip of the beak is straight or curved.
2. On what part of the head are the *eyes* located?

   In the eyes of a bird the following parts are visible: a central *pupil*, and around this a colored region known as the *iris*. State the location and describe the color of each of these parts in the eye of the bird that you are studying.
3. In front of the eyes find two openings, the *nostrils*. Locate the nostrils with reference to the beak and the eyes.
4. Make a drawing twice natural size of a side view of the head to show the beak, eye, and nostril. Label each part shown.

5. Watch a chicken, canary, sparrow, or other bird while it is eating and drinking, and describe the movements that the bird makes in these acts.

C. Organs of locomotion.

1. What is the position of the wings when they are not in use?
2. Note and describe the movements of the wings when the bird is flying.
3. The only part of the leg that is visible in most birds is the foot, the upper parts being covered with feathers.
   - *a.* How many toes do you find pointing forward and how many backward? (Be sure to name the kind of bird on which this observation is made.)
   - *b.* Make a drawing to show the foot and the toes with the claws at the end of each. Label toes and claws.
4. Watch several kind of birds (*e.g.* robins, sparrows, chickens, starlings), and state whether each of these kinds of birds walks or hops.

49. What is a bird? — Birds, like fishes, frogs, and man, belong to the group of animals that have a backbone, and hence are known as *vertebrates*. It is never difficult, however, to distinguish birds from other vertebrates, since every bird has *wings* either developed or undeveloped (Fig. 46) and a covering of *feathers*. Birds, too, maintain a body *temperature* that is higher than that of any other group of animals. The temperature in man, for instance, is normally about 98½° F., whereas no bird, so far as we know, has a temperature less than 100° F., and even 111° F. is known to be the temperature of some of the sparrows and warblers. Hence, we may define *a bird as a warm-blooded vertebrate, having wings and a body covering of feathers and usually able to fly.*

Even a casual examination will show that a bird has a *head*, *neck*, and *trunk*, and two pairs of appendages, namely, the *wings* and *legs*. With the exception of the feet, practically the whole of the animal is covered with feathers (Fig. 46).

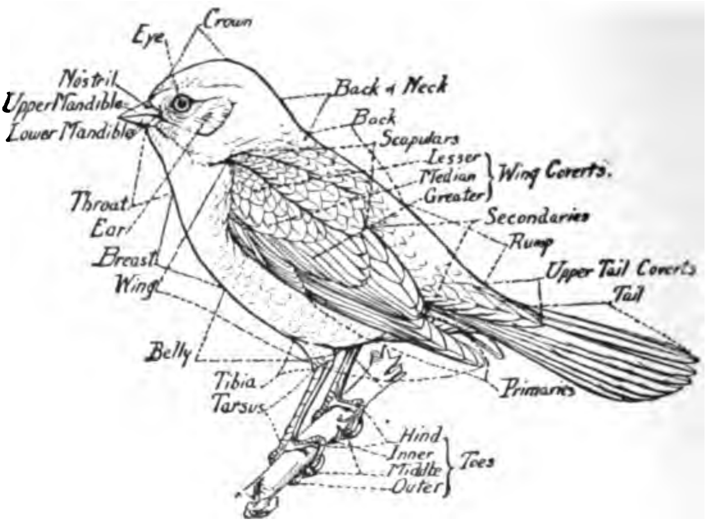

FIG. 46. — External structure of a bird.

50. Head. — A closer study of a bird shows that from the front part of the head projects a horny structure known as the beak or bill. "Tie a man's hands and arms tightly behind his back, stand him on his feet, and tell him that he must hereafter find and prepare his food, build his house, defend himself from his enemies and perform all the business of life in such a position, and what a pitiable object he would present! Yet this is not unlike what birds have to do. Almost every form of vegetable and animal life is used as food by one or another of the species. Birds have most intricately built homes, and their methods of defense are to be numbered by the score; the care of their delicate plumage alone would seem to necessitate many and varied instruments: yet all this is made possible, and chiefly executed, by one small portion of the bird — its bill or beak."[1]

While the size and shape of the bill varies greatly in different kinds of birds, it always consists of two parts (*mandibles*) (Fig. 46), which correspond in position to the upper and lower jaws of man. When the bill is opened, a careful examination shows that a bird has no teeth. Some of the birds that lived ages ago, however, had well-developed teeth in their jaws, as is well shown in (Fig. 47) which is a picture of a bird skeleton restored from bones found in the rocks of western Kansas.

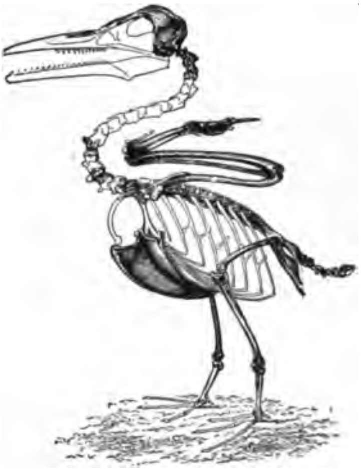
FIG. 47. — Skeleton of a fossil bird.

Near the base of the bill on either side, one can usually see an opening; these openings are the *nostrils*. On the sides of the head are the two *eyes*, and since they bulge out somewhat, the bird is afforded a wide range of vision. If the feathers below and behind the eye are pushed aside, an opening into the *ear* may be seen; this may be made out easily in the head of a chicken.

51. Wings. — In Figure 48 are shown the bones that compose the wing of an ostrich and the arm of a man, and on comparing the two one sees a striking resemblance. In both, the upper arm has a single bone, while in the forearm there are two bones. In the hand region, though the differences are more striking, the general plan of the two is the same. Unlike the bones of the human skeleton those of most birds are hollow and filled with air.

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[1] Beebe, "The Bird."

Any one who has eaten a chicken's wing knows that the bones are covered by muscles; these enable the bird to fold and unfold the parts of the wing, much as the human arm is stretched out or doubled up. On the bird's body are other powerful muscles, which cause the wing as a whole to make the upward and downward strokes in flight.

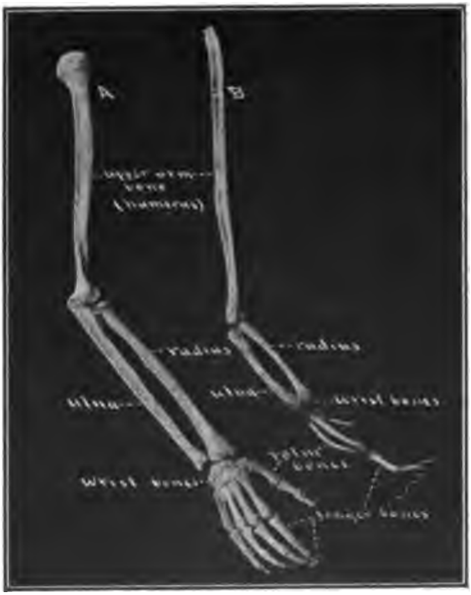

FIG. 48. — *A*, skeleton of arm of a man; *B*, skeleton of wing of an ostrich. (A. E. Rueff.)

Still another wonderful adaptation of the wing for flight is evident in the arrangement and structure of the feathers (Fig. 49). The feathers fit over each other in such a way[1] that in the downward and backward stroke of the wing a continuous surface is struck against the air, and this propels the bird upward and forward. In the upward wing stroke, on the other hand, the resistance of the air is diminished since the feathers are separated more or less like the slats of a Venetian blind, thus allowing the air to pass between them.

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[1] Before assigning these paragraphs the structure of a feather and the arrangement of the feathers on the wing of some bird (*e.g.* a chicken) should be demonstrated to the class.

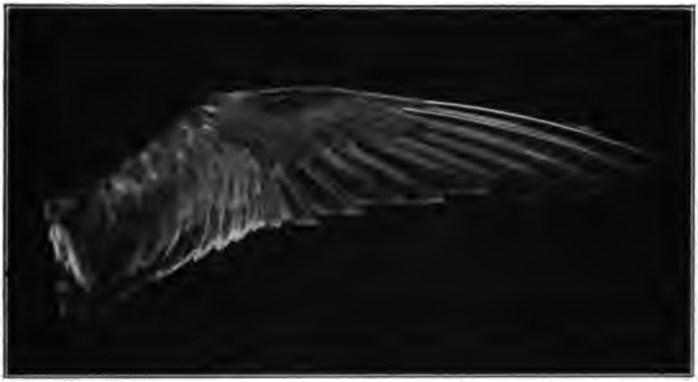

Fig. 49. — Wing of Tern. (Photographed by E. R. Sanborn, N. Y. Zoölogical Park.)

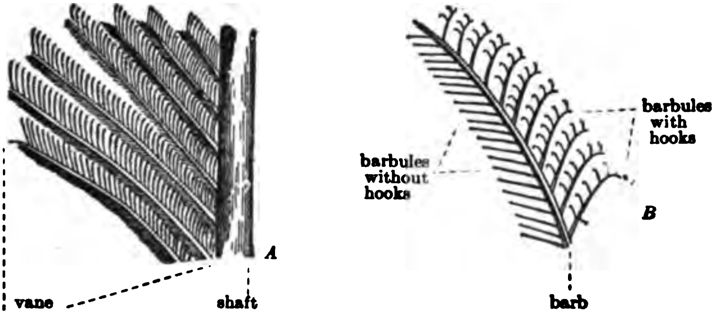

Fig. 50. — Structure of a feather.

An examination of a single feather[1] shows that it consists in the first place of a *shaft* running through its length (Fig.

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[1] See footnote, p. 66.

50, *A*). On the sides of the shaft are the two flat surfaces which make up the *vane*. This vane is composed of slender parts called *barbs* that may be easily separated from each other, or when separated may be readily united, because of little hooks (Fig. 50, *B*). This the bird does when it smooths or "preens" its feathers.

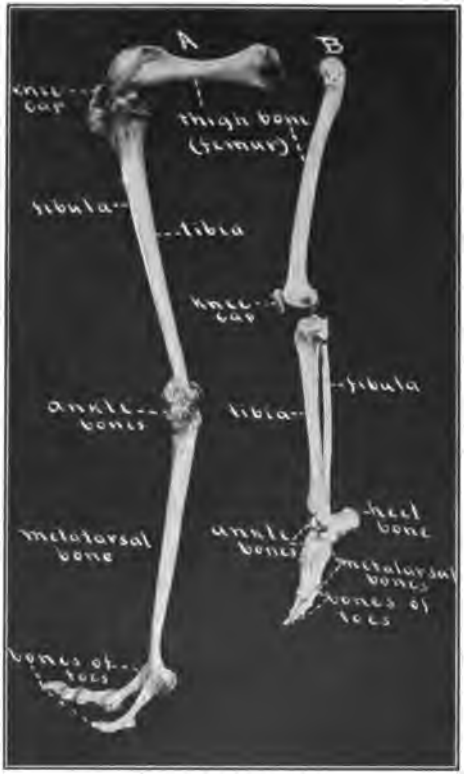

FIG. 51. — *A*, skeleton of leg of an ostrich; *B*, skeleton of leg of a man. (E. R. Sanborn.)

52. Legs. — On comparing the arm of man with the wing of a bird we found that they were similar in structure, and the same is likewise true of the leg and foot. While the thigh of a bird is much shorter proportionately than is that of man (Fig. 51), both have but a single bone. Below the knee of the bird is the shank or "drumstick" which consists of a long bone extending to the ankle, and beside it is a slender bone attached only at the upper end. This region in the leg of man is likewise composed of a relatively thick shin bone, on the outer side of which is a thin bone extending down to the ankle.

The ankle region of a bird is the joint half-way up the leg (Fig. 51, *A*). What is commonly regarded as the bird's foot consists often of three toes that point forward, and one that extends backward. Ordinarily the parts of the leg below the ankle are covered with scales, and the tips of the toes are provided with claws.

63. Study of a hen's egg. — (Optional home work.)

Secure the egg of a hen or other domestic bird, and study it as follows: —

1. Describe the difference in the shape and size of the two ends of the egg.
2. Carefully crack the shell at the larger end and remove the pieces of shell.
    - *a.* State what you have done and describe the *membrane* that lines the shell.
    - *b.* Carefully cut this membrane and note that the liquid contents of the egg do not completely fill the eggshell in this region. This cavity is called the *air space*. Describe the position of this air space.

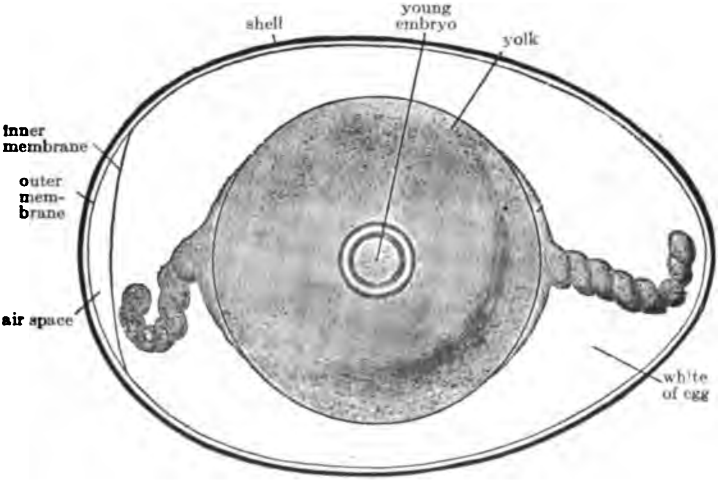

FIG. 52. — Egg of a hen.

3. Pick off the pieces of shell and allow all the contents of the shell to flow out into a cup or deep saucer, taking care not to break the yolk.
   - *a.* State what has been done, and describe the position and color of the white and of the yolk of the egg.
   - *b.* Note two twisted strands extending from the yolk towards each end of the egg. These help to protect the yolk from sudden jars. Describe the position, appearance, and use of these strands.
4. Carefully turn the yolk until you notice a white spot. This spot is the beginning of an *embryo chick*.

   Describe the position and appearance of a young chick embryo.

54. Reproduction and life history. — In the preceding section we have seen that a bird's egg consists of a hard shell, a membrane, the white and the yolk; and that on the outer surface of the latter is a tiny *embryo*. Let us now see how this egg is formed and developed.

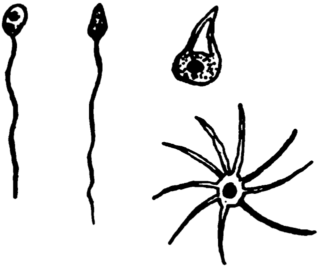

FIG. 53. — Sperm-cells of various animals.

In our study of seed-plants we learned that plant embryos are formed in the ovary of a pistil after an egg-cell has been fertilized by a sperm-cell. In the case of insects (**22**, **27**) and the fish (**104**) we find that egg-cells are produced in organs of the female known as *ovaries* and that before an egg-cell can develop into an embryo (except in rare cases) it must be fertilized by a sperm-cell (Fig. 53) which has been formed in the *spermary* of a male.

If the ovaries of a hen are examined, they will be found to consist of a large number of spherical objects, the larger ones being yellow, which vary in size from tiny dots to full-sized yolks (Fig. 54). If any one of these is examined carefully with a microscope, a single egg-cell may be found. After the yolk has attained its full size and the egg-cell has been fertilized, it receives its coating of white, and the whole is covered with the membranes and the shell.

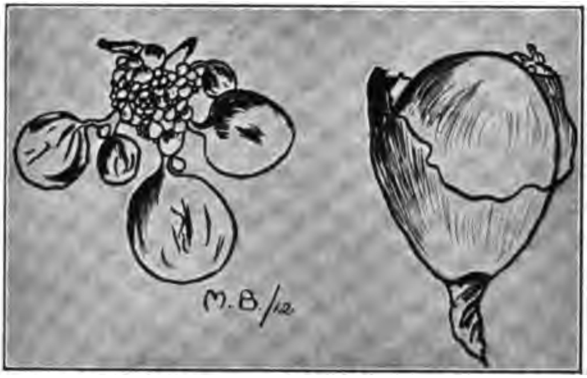

FIG. 54.—Ovary of hen, and egg in egg-tube.

Immediately after fertilization takes place, by the process of cell division many cells are formed. At the time the egg is laid, the chick embryo appears as a tiny white spot on the surface of the yolk when the egg is opened (53, 4). Further development of this embryo, however, cannot take place unless the egg is kept warm. This is brought about when

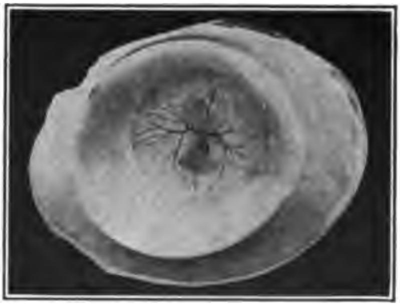

FIG. 55.—Egg of hen, showing embryo chick on surface of yolk. (Beebe, "The Bird.")

the hen broods over the eggs. Gradually the cells of the different external and internal organs are formed (Fig. 55) from the food material furnished by the yolk and the white of the egg, and at the end of three weeks the young chick breaks through the shell, and soon, under the protection of the mother hen, begins to search for food. When first hatched, the feathers are relatively small and downy. The further development of the chick is largely a matter of growth in size and of change in the character of the feathers.

55. Nests and care of young. — The method of reproduction in all birds is much the same as that already described for the chick. Many birds, however, are much more helpless when they emerge from the egg than are chickens, and so they are sheltered in *nests*, and the food of the young birds is brought to them by their parents until they are able to fly and for several days afterwards.

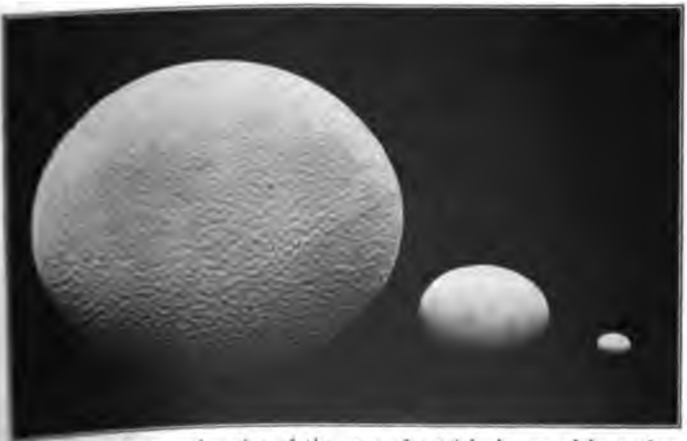

Fig. 56. — Comparative size of the eggs of ostrich, hen, and humming bird. (Photographed by E. R. Sanborn, N. Y. Zoölogical Park.)

Nests differ greatly in their complexity and in the kind of material used. Some birds, for example the gulls and many other sea-birds, usually deposit their eggs on rocky ledges or in slight depressions in the sand along the shore. On the other hand, the Baltimore oriole constructs out of grasses, plant fibers, and strings a marvelous nest hanging high up in the trees, near the outer ends of branches (Fig. 73). Between these two extremes are all gradations of nest complexity.

The eggs laid by birds vary in number, size, and color. The tiny humming bird, for instance, lays two white eggs, each a third of an inch in diameter (Fig. 56); three to five greenish blue eggs, each nearly an inch in diameter, are usually found in a robin's nest, while an ostrich deposits twelve to fourteen eggs, each weighing three to four pounds.

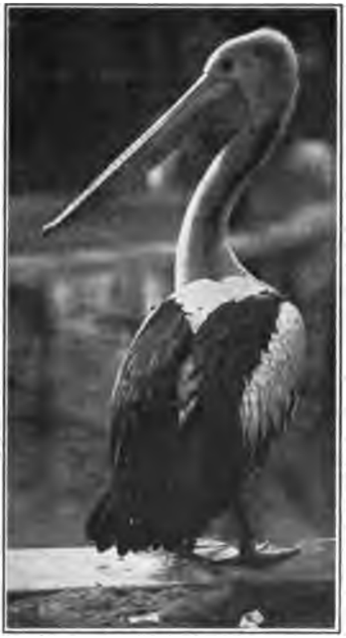

FIG. 57. — The pelican. (Photographed by E. R. Sanborn.)

56. Common methods of classification. — One of the simplest ways of classifying birds is that of dividing them into groups according to the *kind of food* they eat. For instance, we may speak of fish-eating, seed-eating, and insect-eating birds. This, however, is far from being a scientific classification, since birds that differ considerably in structure, and therefore not closely related, frequently live upon the same kind of food. For example, both the pelican (Fig. 57)

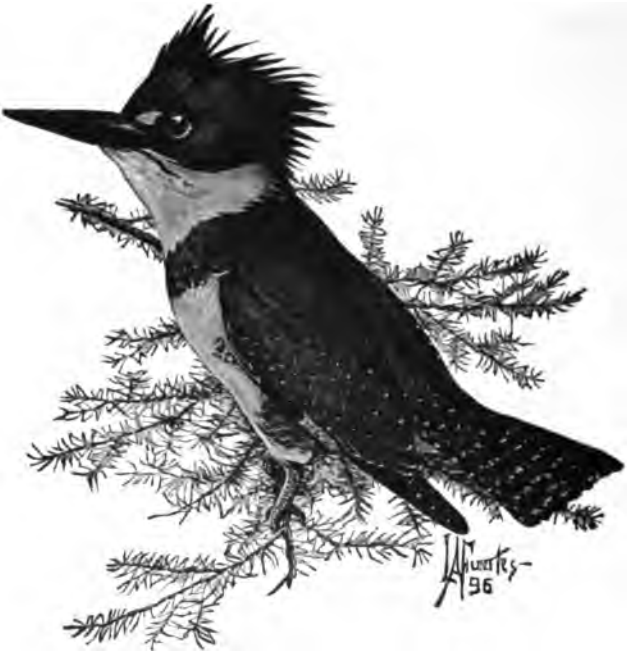

Fig. 58. — Belted kingfisher. (Wright's "Citizen Bird.")

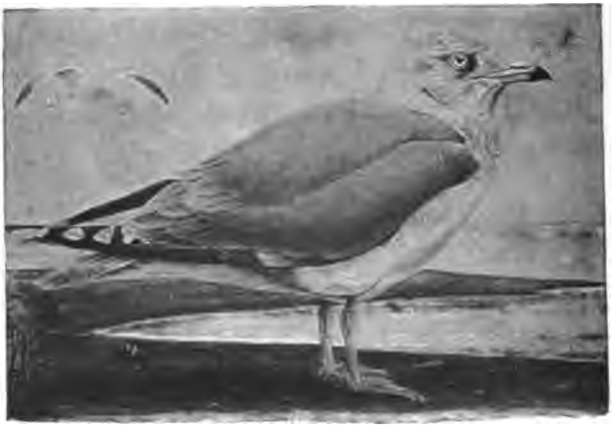

Fig. 59. — Herring gull. (Wright's "Citizen Bird.")

and kingfisher (Fig. 58) catch and eat fish for food, yet a glance at the two figures shows how unlike in form these two birds are.

A second scheme of classification is that based upon their *habitat*. Thus we may speak of water birds, shore birds, marsh birds, and land birds. This plan, too, may group together birds strikingly unrelated in structure and habits, as becomes clear when we compare two land birds like the hawk (Fig. 64), and the sparrow (Fig. 70).

57. Scientific classification of birds. — Modern scientific classification divides the birds of North America into seventeen groups or *orders*, all the birds of a given order resembling each other more or less in structure. The common names given to some of these orders are suggested by their habits. As examples we may name *diving birds* (loon), *long-winged swimmers* (gulls and terns), *scratching birds* (hens, turkeys, and quails), *birds of prey* (eagles, hawks, and owls), and *woodpeckers* (downy woodpecker). The highest order, known as the *perching birds*, is divided into twenty *families*, some of which are the *crow family*, the *sparrow family*, the *warbler*, and the

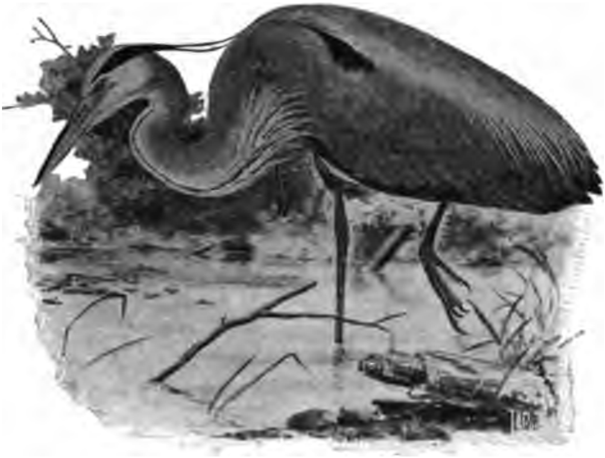

FIG. 60. — Blue heron. (Wright's "Citizen Bird.")

thrush family. The total number of species of the perching birds is far greater than that of all other species taken together. We shall now group together a few of the more closely related orders, and discuss somewhat their characteristic adaptations of structure.

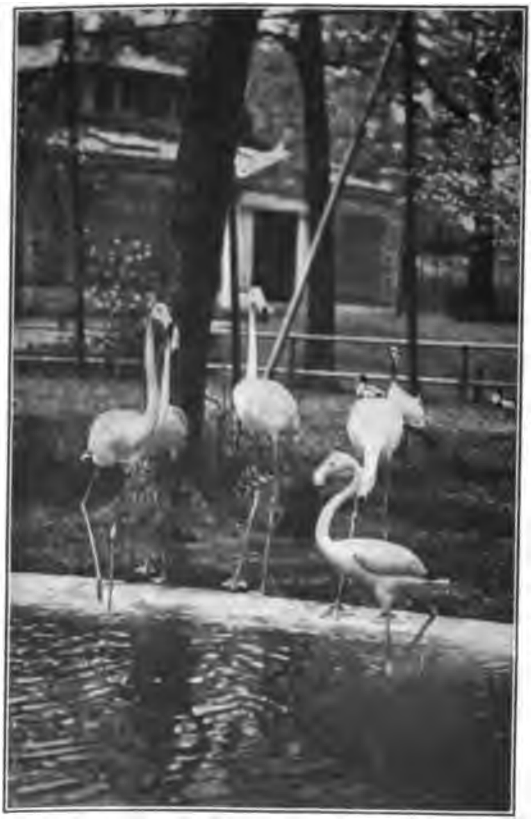

FIG. 61. — Flamingoes. (Photographed in N. Y. Zoölogical Park, by E. R. Sanborn.)

58. Webfooted birds (swimming birds). — In this group we include several orders of birds that have webbed feet, which fit them for swimming in the water. Common examples of such birds are ducks, geese, albatross, and gulls (Fig. 59). Near the tail region of most of these birds an oil gland is developed, from which the bird obtains the oil that it uses in keeping its feathers from getting water-soaked; this is likewise true of all other birds. As one would expect, a large number of these species feed upon fish and other water animals.

59. Wading birds. — All the birds in this group have long, slender legs, which adapt them for wading out into the water for food. Such birds are the herons (Fig. 60), egrets, storks, and cranes. The flamingoes (Fig. 61) have webbed feet like swimming birds, and so they are regarded as connecting links between swimming and wading birds.

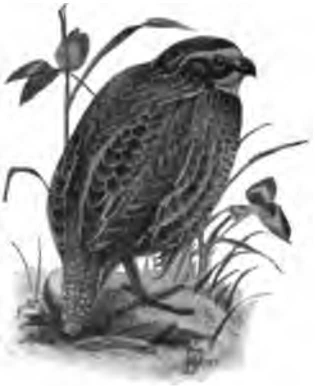

FIG. 62. — Bobwhite.

60. Scratching birds. — This group includes the domesticated chicken and turkey and the quail (Fig. 62). All our various forms of chickens are descended from the

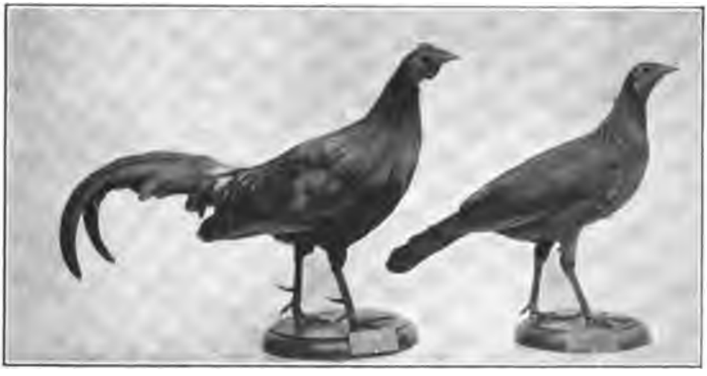

FIG. 63. — Male and female jungle fowl. (Photographed by E. R. Sanborn, from specimens of the American Museum of Natural History.)

small jungle fowl of India (Fig. 63). The wild turkey still exists in some parts of our country, but it is being rapidly exterminated by hunters. The toes of all the scratching birds are armed with strong, blunt nails, by which they are enabled to dig in the soil for insects and worms. All these birds, too, feed to some extent upon grain.

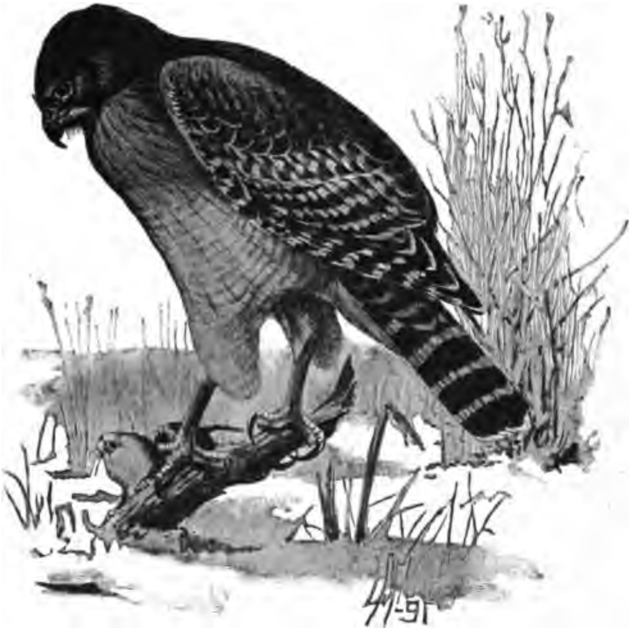

FIG. 64. — Red-shouldered hawk.

61. Birds of prey. — The hawks (Fig. 64), eagles, and owls (Fig. 65), which comprise this group have acquired the name of birds of prey from their habit of catching and feeding on rats, mice, birds, and other animals. Their feet are armed with sharp incurved claws, and the upper part of their bills is hooked; and so they are specially adapted for seizing and tearing their prey.

62. Woodpeckers. — These birds are admirably adapted to creep and climb up the trunks of trees, for they have two clawed toes extending forward, and two backward, and their tail feathers are so stiffened that they serve as props against the bark when the bird is resting (Fig. 66). The food of the woodpeckers is largely composed of insects, which these birds secure by digging them out of the bark or the wood with their stout, chisel-like bills, and then spearing them with their long tongues.

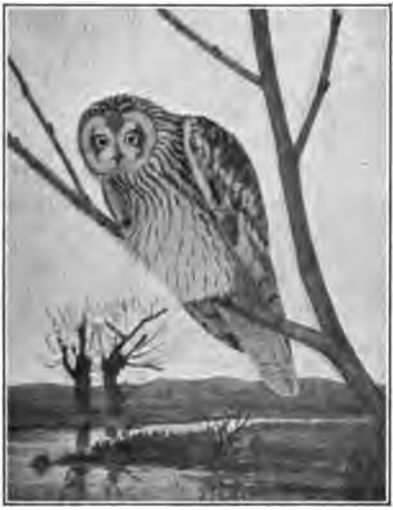

FIG. 65. — Short-eared owl. (Wright.)

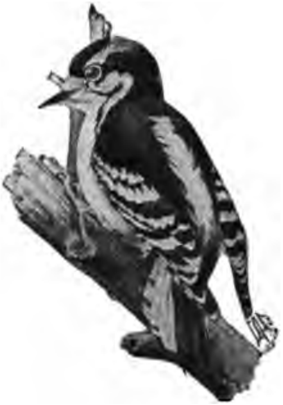

FIG. 66. — Downy woodpecker. (Wright.)

63. Perching birds. — This order, as we have said before, contains by far the largest number of species of birds. All these birds are specially adapted for holding to the limbs of trees, since the mechanism of the leg is so arranged that the toes are automatically clutched to the support upon which the bird is sitting. In this group are included practically all of our bird vocalists, hence the perching birds are often called the "song birds." Among the most beautiful of our songsters are the bobolinks (Fig. 67), catbird, and thrushes (Fig. 68).

The young of all the perching birds, for weeks after they are

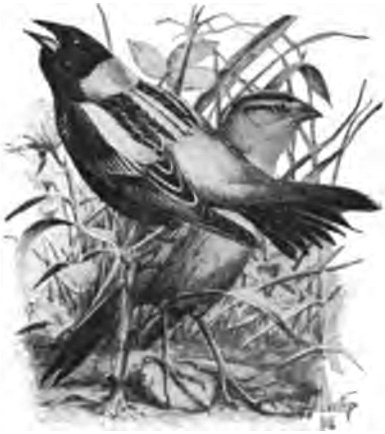

FIG. 67. — Male and female bobolink.

hatched, are helpless in the nests and are unable to feed themselves. Most of the food of young birds consists of the larvæ of insects and some of the families, *e.g.* the fly-catchers (Fig. 69), feed upon insect food throughout their life. The sparrow family (Fig. 70), on the other hand, choose largely a diet of seeds. Almost every kind of food, however, is eaten by some of the perching birds.

64. Migration of birds. — Some of the birds like the chickadee and downy woodpecker, remain in the middle and northern United States throughout the year, and hence are known as *permanent residents* of these regions. Many birds, however, spend the winter

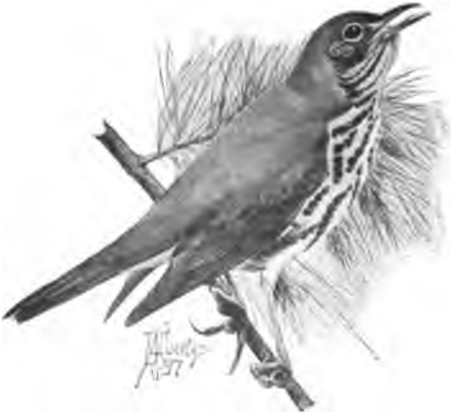

FIG. 68. — Wood thrush.

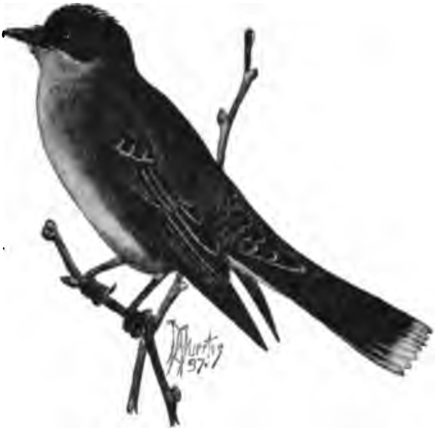

Fig. 69. — Kingbird. (Courtesy of National Audubon Society.)

in the warmer regions of the South and in the spring months move northward; some of them, like the robin (Fig. 71) and the bluebird, build their nests, rear their young, and stay all summer in northern and middle United States. Such birds are called ***summer residents.*** Still other birds rear their young in Canada and even farther north, and come to us only as ***winter visitants.*** This seasonal movement of birds is known as ***migration.*** Migration is

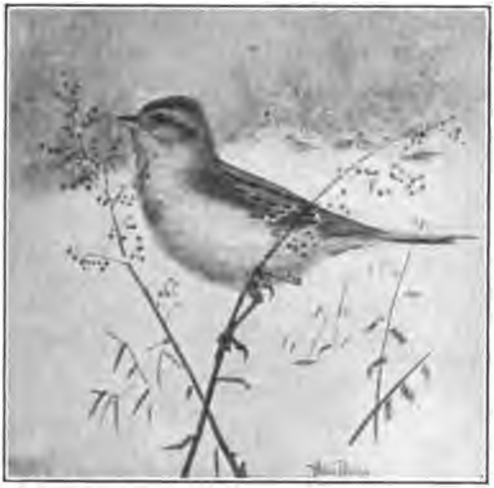

Fig. 70. — Tree sparrow. (Courtesy of National Audubon Society.)

especially characteristic of the perching birds. For this reason, the birds in this, the highest order, are known as "birds of passage."

FIG. 71. — The robin.

DATE WHEN SEEN	PLACE WHERE SEEN	SIZE[1] COMPARED TO ROBIN OR SPARROW	COLOR OF BACK	COLOR OF BREAST	OTHER STRIKING COLORS	NAME OF BIRD
Mar. 10, 1912	Lower limbs of trees	Larger than sparrow	Bright blue	Reddish brown	Belly white	Bluebird

68. Field work on birds. — Pupils should become familiar with the size, form, colors, and song of as many birds as possible, and should note carefully where each kind of bird is most commonly found (*e.g.* in marshes, trees, bushes, or on the ground). In this study bird glasses or opera glasses are very useful. Books like

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[1] Length of robin from tip of bill to tip of tail feathers, about 10 inches; length of sparrow from tip of bill to tip of tail feathers, about 6 inches.

Chapman's "Bird Life," Wright's "Citizen Bird" and "Birdcraft," Hornaday's "American Natural History," should be frequently consulted. In order to record striking characteristics as a help toward identifying birds, it is suggested that each pupil fill out a table as shown on page 82.

66. Importance of birds to man. — Few animals are more beautiful in form and color than are many of our most common birds, and one of the greatest delights of springtime is to greet the return of the bluebirds, tanagers, thrushes, and others of our feathered friends. "To appreciate the beauty of form and plumage of birds, their grace of motion and musical powers, we must know them. . . . Once aware of their existence, and we shall see a bird in every bush and find the heavens their pathway. One moment we may admire the beauty of their plumage, the next marvel at the ease and grace with which they dash by us or circle high overhead. . . . The comings and goings of our migratory birds in springtime and fall, their nest-building and rearing of young, their many regular and beautiful ways as exhibited in their daily lives, stir within us impulses for kindness toward the various creatures which share the world with us. . . . But birds will appeal to us most strongly through their song. When your ears are attuned to the music of birds, your world will be transformed. Birds' songs are the most eloquent of Nature's voices: the gay carol of the grosbeak in the morning, the dreamy, midday call of the pewee, the vesper hymn of the thrush, the clanging of geese in springtime, the farewell of the bluebird in the fall, — how clearly each one expresses the sentiment of the hour or season!" — Quoted from Bulletin No. 3 of University of Nebraska, and from Chapman's "Bird Life."

The value of birds to man as objects of beauty cannot be measured, it is true, in dollars and cents; but were we to lose the birds, we should realize all too well how much they contribute to the happiness of every lover of nature. When, however, we come to discuss the economic value of birds, the good that they do cannot be overestimated. Biologists have carried on long series of studies to determine accurately the food of different kinds of birds. This has been done by watching them while they are eating or while feeding their young, and by examining the contents of birds' stomachs. The following paragraphs contain descriptions of some of the ways in which birds are of inestimable use to man.

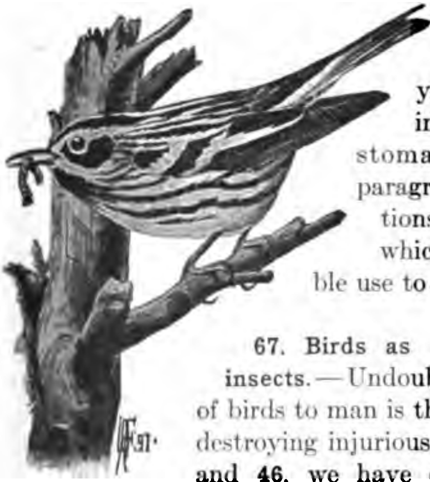

FIG. 72. — Black and white warbler.

67. **Birds as destroyers of harmful insects.** — Undoubtedly the greatest value of birds to man is the good that they do in destroying injurious insects. In **13–18**, **23**, and **46**, we have described some of the ravages made by our insect foes.

"But if insects are the natural enemies of vegetation, birds are the natural enemies of insects. . . . In the air swallows and swifts are coursing rapidly to and fro, ever in pursuit of the insects which constitute their sole food. When they retire, the nighthawks and whip-poor-wills will take up the chase, catching moths and other nocturnal insects which would escape day-flying birds. Fly-catchers (Fig. 69) lie in wait, darting from ambush at passing prey, and with a suggestive click of the bill returning to their post. The warblers (Fig. 72), light, active creatures, flutter about the terminal foliage, and with almost the skill of a humming bird, pick insects from the leaf or blossom. The vireos patiently explore the underside of leaves and odd nooks and corners to see that no skulker escapes. The woodpeckers (Fig. 66), nuthatches, and creepers attend to the trunks and limbs, examining carefully each inch of bark for insects' eggs, and larvæ, or excavating for the ants and borers they hear within. On the ground the hunt is continued by the thrushes (Fig. 68), sparrows (Fig. 70), and other birds that feed upon the innumerable forms of terrestrial insects. Few places in which insects exist are neglected; even some species which pass their earlier stages or entire lives in the water are preyed upon by aquatic birds."[1] — From CHAPMAN'S "Bird Life."

As examples of the number of insects destroyed by individual birds we may give the following: Six robins in Nebraska ate 265 Rocky Mountain locusts; the stomachs of four chickadees contained 1028 eggs of cankerworms; 101 potato beetles were found in the stomach of a single quail (Fig. 62); and 250 hairy caterpillars, which other birds do not eat, were devoured by a yellow-billed cuckoo. (Frontispiece.)

68. Birds as destroyers of weed seeds. — Another way in which birds are useful to man is in the destruction of weed seeds. Most perching birds that feed largely upon seeds, *e.g.* the sparrows and finches, have stout, conical bills (Fig. 70) which are specially adapted for crushing seeds. In one of the pamphlets of the United States Department of Agriculture, entitled "Some Common Birds and their Relation

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[1] Before assigning this section for study each of the birds named should if possible be shown to the class, or at least colored pictures of the birds, *e.g.* in Chapman's "Bird Life."

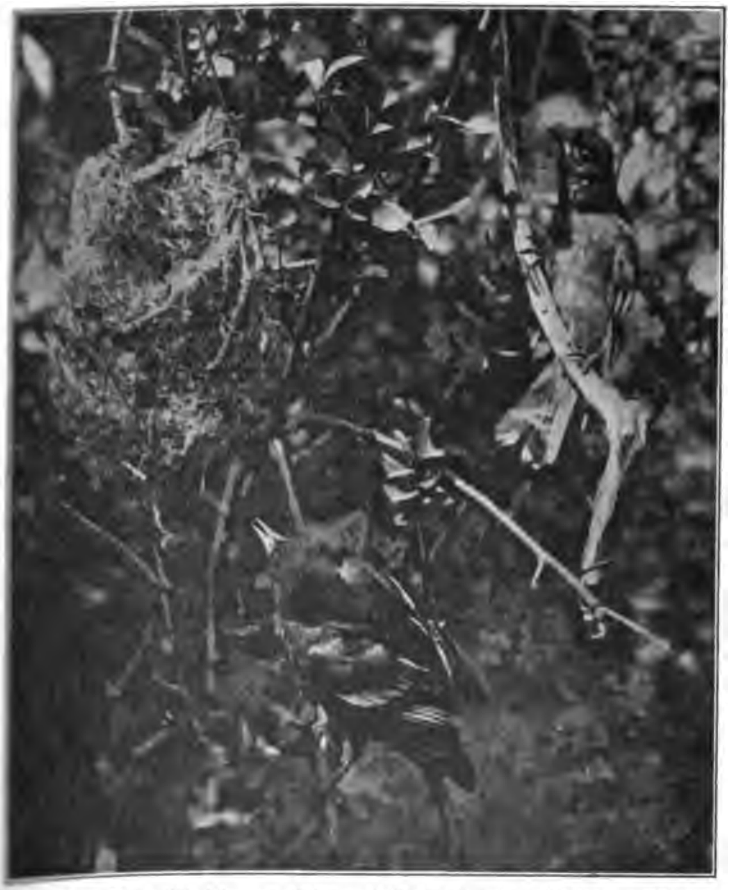

FIG. 73. — Nest of Baltimore oriole; male bird below, female above. (Photographed by A. E. Rueff of the Brooklyn Institute of Arts & Sciences.)

to Agriculture," the writer estimated that in the state of Iowa during the six months of fall and winter, tree sparrows devoured 875 *tons of weed seed.* An actual count of the stomach contents of a bobwhite showed the presence of 400 pigweed seeds. In the stomach of another were 500 seeds of ragweed.

69. Birds as destroyers of rats and mice. — We learned in **61** that hawks and owls by their hooked bills and claws are admirably fitted to clutch and tear living prey. It has been demonstrated that the food of many of these birds consists almost wholly of small gnawing mammals (*e.g.* field mice) (Fig. 64) which are exceedingly injurious in fields of grain. An examination of the stomachs of fifty short-eared owls (Fig. 65) showed that 90 per cent of them contained nothing but mice. Forty of the forty-nine stomachs of the rough-legged hawks were found to contain mice, while most of the rest contained injurious animals.

70. Birds as scavengers. — Some birds of prey, like the turkey buzzards of the Southern states, eat animals that are dead. "These animals may be seen at all hours of the day sailing through the air in majestic circles or lazily resting on stumps or trees after a feast of their filthy food. They perform an important service as scavengers, disposing of all sorts of animal matter that would pollute the air. On this account they are seldom molested by man and in some States are protected by law. They devour both fresh and putrid meat. . . . They are known sometimes to capture live snakes and to attack helpless animals of many kinds. Along the seashore they feed upon dead fish cast up by the waves." — WEED and DEARBORN, "Birds in their Relations to Man." Gulls (Fig. 59) also serve a useful purpose by devouring dead fish and other refuse along our coast line and in our harbors.

71. Birds injurious to man. — We have discussed briefly in the preceding sections some of the ways in which birds are of incalculable value to man. It must be admitted, however, that some birds are of doubtful value, while others are positively injurious. As an example of a bird, which, to say the least, is a nuisance, we may mention the common English sparrow. This bird was first introduced from England into the United States in Brooklyn, N.Y., in 1851, because it was expected to attack some of our injurious insects. These sparrows have multiplied so rapidly that now they are found practically everywhere in the United States. " As destroyers of noxious insects, the sparrows are worse than useless." Thus, for instance, the stomach of a single cuckoo (Frontispiece) was found to contain more insects than did the stomachs of 522 English sparrows.

But even more serious are the positive charges that have been proved against this bird. It pecks at and destroys the young buds of trees, and later injures many fruits while they are ripening. It causes great losses in the grain fields from the time of planting to that of harvesting; and worst of all is the fact that it molests and drives away our native song and insect-eating birds.

The crow (Fig. 74) is another bird that on the whole is probably more injurious than beneficial for the following reasons: " (1) Crows seriously damage the corn crop, and injure other grain crops, usually to a less extent. (2) They damage other farm crops to some extent, frequently doing much mischief. (3) They are very destructive to the eggs and young of domesticated fowls. (4) They do incalculable damage to the eggs and young of native birds. (5) They do much harm by the distribution of seeds of poison ivy, poison sumach, and perhaps other noxious plants. (6) They do much harm by the destruction of beneficial insects. On the other hand: (1) They do much good by the destruction of injurious insects. (2) They are largely beneficial through their destruction of mice and other rodents. (3) They are valuable occasionally as scavengers." — W. B. BARROWS, "The Food of Crows."

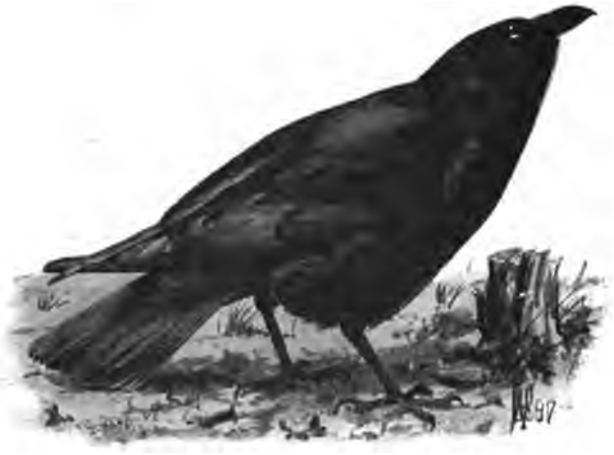

FIG. 74. — The crow.

While most of the hawks are undoubtedly beneficial **(69)**, two species, namely, Cooper's hawk and the sharp-shinned hawk, must be kept down to limited numbers. Both of these are "chicken-hawks," and in addition they ruthlessly destroy great numbers of our most valuable wild birds.

72. Summary of the relation of birds to human welfare. — Library study.

For further facts like the following, consult, Weed and Dearborn's "Birds and their Relation to Man," Forbush's "Useful Birds and their Protection," Hornaday's "American Natural History," pamphlets of Department of Agriculture (which may be obtained free from Washington, D.C., and from State Departments of Agriculture), and articles on birds and insects in Encyclopedias.

NAME OF BIRD	TIME OF VISITATION	KIND OF ANIMAL FOOD EATEN	KIND OF VEGETABLE FOOD EATEN	REMARKS
Robin . . .	Summer resid.	Insects, 42 per cent	Small fruits and berries, mostly wild, 58 per cent	Beneficial
Phœbe . . .	Summer resid.	Insects caught on wing, 93 per cent	Wild fruits, 7 per cent	Beneficial
Hairy woodpecker . . .	Perm. resid.	Wood-boring insects and ants	Wild fruits	Beneficial
Yellow-billed cuckoo . .	Summer resid.	Insects, largely hairy caterpillars		Beneficial
Quail or bob-white . . .	Perm. resid.	Insects in summer	Weed seeds during rest of year	Beneficial
Tree sparrow .	Winter visit.		Weed seeds	Beneficial
Bobolink . .	Summer resid.	Insects in North	Rice in South	$2,000,000 loss to rice crop
Short-eared owl	Perm. resid.	Rats, mice and other small mammals		Beneficial

NAME OF BIRD	TIME OF VISITATION	KIND OF ANIMAL FOOD EATEN	KIND OF VEGETABLE FOOD EATEN	REMARKS
Sparrow-hawk	Summer resid.	Mice and insects		Beneficial
Cooper's hawk	Summer resid.	Poultry and song birds		Injurious
Sharp-shinned hawk . . .	Summer resid.	Poultry and song birds		Injurious
Crow	Perm. resid.	Insects, mice, eggs and young of other birds	Corn and other crops, weed seeds	Doubtful value
English sparrow	Perm. resid.	Insects rarely	Buds, fruit, grain	Drives away useful birds

73. Causes of decrease in bird life. — Certainly enough has been said to show that when all things are considered birds are exceedingly useful to man. One would therefore expect that every possible means would be taken to protect all kinds of valuable birds. Yet what do we find? "To-day the first thing to be taught is the fact that from this time henceforth *all birds must be protected, or they will all be exterminated.* To-day, it is a safe estimate that there is a loaded cartridge for every living bird. Each succeeding year produces a new crop of gun-demons, eager to slay, ambitious to make records as sportsmen or collectors. If a bird is so unfortunate as to possess plumes, or flesh which can be sold for ten cents, the mob of pot-hunters seeks it out, even unto the ends of the earth." — HORNADAY'S "The American Natural History."

A careful investigation made in 1897 for the New York Zoölogical Society showed that during the fifteen years between 1883 and 1898 in all but four states[1] the number of birds had strikingly decreased. For example, in New York State the decrease was 48 per cent, or almost one half; in Florida it was over three fourths, while the average for the whole country was 46 per cent. Among the principal reasons given by the 180 careful observers who assisted Dr. Hornaday in the foregoing inquiry were the following: "(1) sportsmen and so-called sportsmen, (2) boys who shoot, (3) market hunters and pot-hunters, (4) plume-hunters and milliners' hunters, . . . (6) egg-collecting, chiefly by small boys, (7) English sparrow, . . . (9) Italians, and others, who devour song birds."

74. Destruction of birds by cats. — "As the cat is not an actual necessity, and as it is a potent carrier of contagious diseases, which it spreads, particularly among children, it would be far better for the community if most of the bird-killing cats now roaming at large could be painlessly disposed of. . . . Where the cat is deemed necessary in farm or village, no family should keep more than one good mouser, which should never be allowed to have its liberty during the breeding season of birds. . . . Cats can be confined during the day in outdoor cages as readily as rabbits, and given the run of the house at night." — FORBUSH, "Useful Birds and their Protection."

75. Destruction of birds by boys. — One of the most serious menaces to our native bird life is the small boy who has the "egg-collecting fever." All the eggs he can find in his keen-eyed searches through the woods and fields are destroyed to increase his collection. If this served any really useful purpose, the resulting wholesale destruction of birds might possibly have some justification. But ninety-nine out of a hundred of these collections are soon forgotten and become useless without having made any real contribution to the knowledge of the possessor.

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[1] Kansas, Wyoming, Utah, and Washington were the only states that showed an increase in bird life.

The small boy, too, unfortunately carries his destructive work among birds still further, as the following typical incident will show. A biologist reports meeting near Washington, D.C., " one such youngster, and upon examining his game bag found it absolutely full of dead bodies of birds which he had killed since starting out in the morning. One item alone consisted of seventy-two ruby and golden-crowned kinglets. The fellow boasted of having slain over one hundred catbirds that season."

76. Destruction of birds for food. — In the early days of the white settlements in North America, the game birds like the grouse and duck were abundant and they were of necessity killed, as were other wild animals, for food. Later on began the killing of birds for sport. As the forests were cut down, the birds had less and less protection, and had not legislation intervened, the game birds would long since have been exterminated. As it is, they have been killed faster than they breed; and this means ultimate extermination.

To this destruction of game birds for food, in more recent times has been added the wholesale slaughter of many of our smaller birds like the thrushes, sparrows, warblers, and woodpeckers. It is claimed that this has been largely due to the demands of our immigrant population in the North and to the negroes in the South. " However, there is scarcely a hotel in New Orleans," says Professor Nehrling, " where small birds do not form an item on the bill of fare. At certain seasons the robin, wood thrush, thrasher, olive-backed thrush, hermit thrush, chewink, flicker, and many of our beautiful sparrows form the bulk of the victims; but catbirds, cardinals, and almost all small birds, *even swallows*, can be found in the markets."

77. Destruction of birds for millinery purposes. — Even more ruthless than the slaughter of birds for food by boys and by men is that caused by the demand for birds for millinery purposes. Here the final responsibility rests upon women alone. A single dealer in the South declared that in the course of a single year he handled 30,000 bird skins, the largest part of which were used in the decoration of hats.

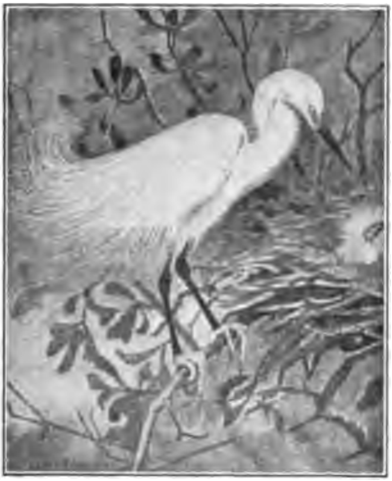
FIG. 75. — Egret, nest, and young. (Courtesy National Audubon Society.)

The Florida egret heron (Fig. 75) has been practically exterminated for this purpose. "Twenty years ago," says Chapman, "it was abundant in the South, now it is the rarest of its family. The delicate 'aigrettes' which it donned as a nuptial dress were its death warrant. Woman demanded from the bird its wedding plumes, and man has supplied the demand. The Florida herons or egrets have gone, and now he is pursuing the helpless birds to the uttermost parts of the earth. Mercilessly they are shot down at their roosts or nesting grounds, the coveted feathers are stripped from their backs, the carcasses are left to rot, while the young in the nest above are starving."

"This slaughter of the innocents is by no means confined to the Southern states. During four months 70,000 bird skins were supplied to the New York trade by one Long Island village. 'On the coast line of Long Island,' wrote Mr. William Dutcher, not long ago, 'the slaughter has been carried on to such a degree that, where, a few years since, thousands and thousands of terns (Fig. 76) were gracefully sailing over the surf-beaten shore and the wind-rippled bays, now one is rarely to be seen.' Land birds of all sorts have also suffered in a similar way, both on Long Island and in adjacent localities in New Jersey. Nor have the interior regions of the United States escaped the visits of the milli-

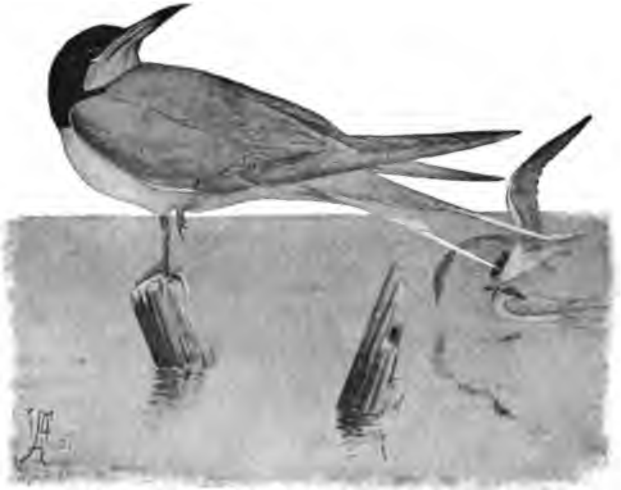

FIG. 76. — Tern.

ner's agent. An Indianapolis taxidermist is on record with the statement that in 1895 there were shipped from that city 5000 bird skins collected in the Ohio Valley. He adds that 'no county in the state is free from the ornithological murderer,' and prophesies that birds will soon become very scarce in the state.

" These isolated examples can only suggest the enormous number of birds that are sacrificed on the altar of fashion. The universal use of birds for millinery purposes bears sufficient testimony to the fact. Yet it is probable that most women who follow the fashion seldom appreciate the suffering and the economic losses that it involves." — WEED and DEARBORN, "Birds in their Relations to Man."

78. Effects of bird destruction. — While the æsthetic loss to mankind resulting from the destruction of our wild birds cannot, as we have said, be computed, yet even in the cities this loss is beginning to be realized as we see the song birds in the parks steadily diminishing in number. Everyone, however, is affected by the increasing cost of our food supply, and we have but to review the facts stated in the preceding sections to show that the destruction of our wild birds has a very important bearing on the present situation.

Every farmer knows that it is impossible to raise the crops of a single year without battling with insect pests. The time and expense involved in applying insect-destroying preparations would be difficult to compute, and even after the year's contest is ended, the insects are often victorious. In ruthlessly destroying the wild birds man has interfered with the " balance of nature" and so has helped the ravaging hordes of insects and gnawing animals to multiply without adequate check. All this means that we, the consumers of the fruits, the vegetables, and the grains, must pay higher prices for the food we eat and the clothes we wear.

79. Conservation of birds. — But it is not yet too late to save the remnant of the birds still left to us, and even to increase the bird life of our country. It is evidently necessary, however, in the first place, that laws similar to the following should be passed in every state.

"The Bird Law of the American Ornithologists' Union. — An Act for the Protection of Birds and their Nests and Eggs.

"Section 1. — No person shall within the State of —— kill or catch or have in his or her possession, living or dead, any wild bird other than a game bird, nor shall purchase, offer, or expose for sale any such wild bird after it has been killed or caught. No part of the plumage, skin, or body of any bird protected by this section shall be sold or had in possession for sale.

"Section 2. — No person shall within the State of —— take or needlessly destroy the nest or the eggs of any wild bird nor shall have such nest or the eggs in his or her possession. . . .

"Section 3. — Any person who violates any of the provisions of this act shall be guilty of a misdemeanor, and shall be liable to a fine of five dollars for each offense, and an additional fine of five dollars for each bird, living or dead, or part of bird, or nest and eggs possessed in violation of this act, or to imprisonment for ten days, or both, at the discretion of the court.

"Section 4. — Sections 1, 2, and 3 of this act shall not apply to any person holding a certificate giving the right to take birds and their nests and eggs for scientific purposes, as provided for in Section 5 of this Act. . . .

"Section 7. — The English or European house sparrow (Passer domesticus) is not included among the birds protected by this act."

"In addition to the above, every state that has not already done so, should at once enact laws to prohibit the sale of all wild game at all seasons, and to stop all shooting of game in late winter and spring. About one half the states have done this, and the other half should act without delay. The sale of game has almost destroyed our once magnificent supply of game birds. We have no right to hand down to posterity a gameless continent. The wild life of to-day is not wholly ours to dispose of as we please. It has been given to us *in trust.* We must account for it to those who come after us and audit our records."[1] — Dr. W. T. HORNADAY.

But laws, however stringent, are of little avail unless there is a healthy public sentiment to bring about their enforcement. Thus, for instance, it is evident that laws merely designed to prevent the killing of birds for millinery purposes will be ineffective, so long as women are permitted to wear birds. One thing will completely stop the cruelty of bird millinery — the disapprobation of fashion. "It is our women who hold the great power. Let our women say the word, and hundreds of bird lives will be preserved every year. And until woman does use her influence it is vain to hope that this nameless sacrifice will cease until it has worked out its own end and the birds are gone." — WEED and DEARBORN, "Birds in their Relations to Man."

80. What boys and girls can do to protect birds. — "Now that adequate statutes are either enacted or may reasonably be expected very soon, it remains to scatter information about birds everywhere, so that laws may be respected . . . and it is in this line that those interested in their conservation should work. There must be lectures, short articles of a popular nature in newspapers and magazines, distribution of government and other publications relating to birds, posting bird laws in conspicuous places, and most important of all, systematic bird work in public schools. The importance of engaging the interest of our youth in birds cannot be overestimated. It results in a double benefit, for the birds will be held in higher esteem and the children will become possessed of a source of lasting pleasure. The nest-robbing, bird-shooting boy and the feather-wearing girl may be made the friends and allies of the birds." — WEED and DEARBORN, "Birds in their Relations to Man."

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[1] The authors are indebted to Dr. W. T. Hornaday, of the New York Zoölogical Park, for many suggestions relating to conservation of birds and for a careful reading of the chapters on birds and fishes.

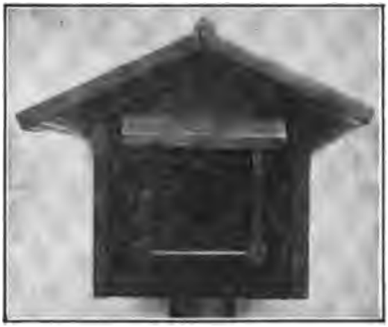
FIG. 77. — Bird house made by a twelve-year-old boy.

But not only should the boy cease to destroy nests and shoot birds; not only should the girl cease to wear any part of a wild bird; but boys and girls alike should do all they can to induce others to do likewise. Much may also be done, likewise, even in the vicinity of large towns, to attract birds and induce them to nest. In the first place, the nests and eggs of the English sparrow should be destroyed whenever found. Stray cats should be kept from harming birds. Pieces of meat, bones, and suet, when hung in the trees in winter time, and crumbs and grains scattered about, will serve to attract the winter visitants and, when thus attracted, these birds devour great numbers of the eggs and insects in the hibernating stages that during the following season would attack the fruit and shade trees. And finally, any ingenious boy can construct and put in the trees bird houses that in the springtime would become the nesting places of bluebirds, wrens, tree swallows, and martins.[1] (Fig. 77.)

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[1] For other methods of encouraging birds see Weed and Dearborn, "Birds in their Relations to Man," pp. 304–315. Trafton, "Methods of Attracting Birds," and leaflets of National Association of Audubon Societies, 1974 Broadway, N. Y., *e.g.* No. 16 (Winter Feeding of Wild Birds) and No. 18 (Putting up Bird Boxes), 1 cent each.

CHAPTER III

FROGS AND THEIR RELATIVES

81. Study of the frog. — Laboratory study.

A. Regions and appendages. — The frog's body consists of two principal parts, or regions; namely, the *head* and *trunk*. The line of union between the two regions is just in front of the anterior appendages (arms).

1. Locate the appendages (*arms* and *legs*) attached to the trunk.
2. Name and locate the organs that you find on the head, giving the number of each.

B. Breathing organs.

1. Describe the location of the nostrils on the head.
2. Examine a preserved specimen in which a stiff bristle has been passed through one of the nostrils.
   - *a.* Tell what was done.
   - *b.* Into what cavity has the bristle emerged?
   - *c.* (Optional.) What is one difference, therefore, between the nostrils of a fish and of a frog? (See **102**, 2 *b*.)
   - *d.* In what region (anterior or posterior) of the roof of the mouth cavity are the inner openings of the nostrils located?
3. (Demonstration.) Just back of the tongue there is a narrow opening that leads into the windpipe (*trachea*). This opening is called the *glottis*.
   - *a.* Locate the glottis.
   - *b.* Does the glottis extend lengthwise or crosswise of the mouth cavity?
   - *c.* Into what does the glottis open?
4. Examine a dissected frog prepared in such a way as to show the lungs.

   a. State the location of the lungs with reference to the head and the cavity of the trunk.
   b. Describe the appearance of the lungs.
   c. Insert the end of a glass tube, that has been drawn out to a small diameter, into the glottis opening and blow air into the lungs. Describe what you have done and state the result.

5. Name in order the openings, the cavity, and the tube through which the air must pass in order to reach the lungs.

C. Breathing movements.

1. Place a frog in a glass jar with an inch or two of water and watch the action of the floor of the mouth. This is one of the breathing movements. Describe this breathing movement of the frog.
2. There are two breathing movements of the sides of the trunk, one a very active inward and outward movement, and the other a very slight inward and outward movement. When you have seen these two kinds of movements of the sides, describe them and state which kind occurs the more frequently.

D. How the frog exhales.

1. What effect will the active inward movement of the sides have upon —
   a. The size of the body cavity?
   b. The size of the lungs?
   c. The pressure of the air in the lungs?
2. When the sides of the trunk move actively inward, will the air move into the lungs or out? Why?
3. Through what passages will the air go from the lungs to the outside of the frog?

E. How the frog inhales.

1. When the floor of the mouth moves downward —
   a. Will the size of the mouth cavity be made larger or smaller?

   b. If the nostrils are now open will the air move into the mouth cavity or out? Why?

2. When the floor of the mouth is raised —
   a. Will the size of the mouth cavity be increased or decreased?
   b. Will the pressure of the air in the mouth cavity be increased or decreased?
   c. If both the nostrils and the glottis are now open, in what directions will air be forced?
   d. What causes the slight outward movements of the sides of the trunk in the region of the lungs?

F. How the lungs are fitted for breathing organs. (Suggested as home work.)

When the lungs are inflated (see *B*, 4 above) they look like bags (Fig. 80). The lungs are hollow, and their walls are composed of thin material. In these membranous walls are thin-walled blood vessels known as *capillaries.* The heart forces blood that has come from the body into these capillaries of the lungs, and then back to the heart. Bearing in mind that respiration in animals is essentially the same as in plants (P. B., 82) —

1. State what waste substance the blood brings to the lungs to be given off from the capillaries.
2. What gas will the blood in the capillaries take up from the air in the lungs?
3. How are the walls of the lungs and of the capillaries of the lungs fitted by structure to make this interchange of gases possible?

G. Food-getting.

To the Teacher. — Select a number of as large preserved or freshly killed frogs as you can get. Open the jaws as far as possible and keep them in this position by means of small pieces of wood.

1. Seize the posterior or hind end of the tongue and pull it forward.
   - *a.* Tell what you have done and state which end of the tongue is attached to the floor of the mouth.
   - *b.* Describe the shape of the tip end of the tongue.
2. The living frog can extend its tongue much farther than you have been able to do in the case of the preserved frog, and in the living frog the tongue is covered with a very sticky substance. The tongue is used to catch insects at some distance from the animal (Fig. 79). Tell how you think the frog could use its tongue to catch insects and get them into its mouth.[1]
3. Look for teeth on the jaws of a skeleton of a frog, or if you cannot obtain a skeleton, rub the finger over the jaws of a preserved specimen.
   - *a.* Which of the jaws has teeth?
   - *b.* Describe the location of the teeth on the jaw.
   - *c.* State the shape and size of the *jaw teeth*.
   - *d.* What is the probable use of the jaw teeth?
4. (Optional.) Look on the roof of the mouth for two relatively large *palate teeth*. Rub the fingers over the surface of the palate teeth.
   - *a.* Tell what you have done.
   - *b.* What have you found out about the palate teeth?
   - *c.* What is the probable use of the palate teeth?

H. How a frog swallows.

1. Gently touch the eyes of a living frog until it draws them into the head. Tell what you have done and observed.
2. Look at the roof of the mouth of a preserved specimen while you push the eyes into the head. Tell what you have done and describe the effect produced in the roof of the mouth.
3. How will the act of pushing the eyes into the head be useful to a frog in swallowing?[1]

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[1] If possible live frogs should be fed on meal worms, or other insects, and the feeding movements observed.

I. (*Optional.*) *Sketch of the mouth cavity.*

1. Open wide the mouth of a large frog and make a sketch to show the shape of the mouth cavity twice the natural size, and the shape and thickness of the upper and lower jaws.
2. Draw the following parts to show their location, size, and shape: jaw teeth, palate teeth, tongue, glottis, nostril openings, swellings caused by the eyes.
3. Farthest back in the throat find an opening that extends crosswise. It is the opening into the *gullet* and is just behind the glottis. Push the handle of the forceps into this opening and draw it (in your sketch) partly opened.
4. Label upper jaw, lower jaw, jaw teeth, palate teeth, tongue, glottis, opening of gullet, nostril openings, swellings caused by eyes.

J. *Structure of arms and leg*

Place a frog in a glass jar at least half full of water to cause the animal to extend the hind legs.

1. Make a sketch (natural size) of an arm to show the shape and size of the following parts: upper arm, elbow, forearm, hand, number of fingers. Label each part.
2. Draw one of the legs (natural size) to show the following parts: thigh (next the body), knee, shank, ankle (elongated region above foot), foot, toes, web between toes. Label each part.

K. How a frog swims.

Place an active frog in a sink or other receptacle large enough to afford it room to swim. The water should be deep enough so that the frog will not strike the bottom with the legs. Get the frog to swim the full length of the receptacle as many times as may be necessary to answer the following: —

1. Tell what you have done.
2. Describe the movements of the hind legs in swimming.
3. In which of these movements are the toes spread out?
4. In which of these movements, therefore, can the frog get the best hold upon the water?
5. In which direction must the frog push the harder in order to move in the direction that it does?
6. In what respects are the posterior appendages well fitted for swimming?
7. In what respects are the anterior appendages not as well fitted as the legs for swimming?

L. How a frog jumps.

Place a frog where there is plenty of room, and get it to jump as many times as necessary to answer the following: —

1. Tell what you have done.
2. Describe the position of the parts of the legs just before the frog jumps.
3. Describe the two movements made by the parts of the leg in the act of jumping and when about to land.
4. In which of these two movements must the frog use the greater force?
5. Which movement, therefore, throws the frog into the air?
6. In what respects are the legs better adapted for jumping than the arms?

N. Internal organs.

To the Teacher. — Put into a covered jar enough frogs to supply each two students with a specimen. Put into the jar some ether, or better, saturate a small sponge with the ether and place it in the jar. When the animals are dead, dissect them as follows: lift up the skin of the ventral wall of the abdomen with the forceps; carefully insert the point of the scissors near the posterior end of the trunk, and carefully cut forward on one side of the body as far as the tip of the head, and back on the other side of the trunk, until the skin is completely removed from the ventral surface. In a similar manner remove the muscular wall that covers the trunk, being careful not to injure the internal organs. If time allows, remove also the skin from one leg; call attention to the thinness of the skin and to the underlying blood vessels; show the characteristics and action of the leg muscles.

If the specimen is a female, remove nearly all the eggs and throw them away. Insert a blowpipe in the glottis and partly inflate the lungs. Wash the specimens thoroughly to remove all traces of blood and cover them with water in a dissecting pan.

If the specimens are needed on successive days, they should be wrapped in a wet cloth immediately after the class work of each day and kept in a cold place. Use only specimens that are fresh.

1. Make an outline drawing, natural size (or twice natural size if the frogs are small), of the ventral view of the head and trunk regions of a dissected specimen, together with the base of each of the four appendages, and *draw nothing else until directed to do so.*
2. The *heart* is a cone-shaped body midway between the arms. Draw the heart to show its position, shape, and relative size.
3. On either side of the heart are the *lungs*. Stretch one of them a little by pulling on it; then letting it go.
   - *a.* State whether or not the lungs are elastic. Are they hollow or solid? Of what advantage are these two characteristics of structure?
   - *b.* What is the color of the lungs? State whether or not you find tiny blood vessels on the surface.

c. Draw the lungs in position to show their situation, size, and shape.

4. On the frog's right side, and behind the heart and lungs is the reddish, several-lobed *liver*. Lay the liver over to one side and find between the lobes on the underside a thin-walled, green sac, the *bile sac* (or *gall bladder*). Sketch in your drawing the liver to show it in this position together with the gall bladder.
5. On the frog's left side and under the liver in its natural position is a whitish, oblong body, which narrows at its hinder end. This body is the *stomach*. Push the handle of the dissecting needle down the gullet into the stomach.
   a. Tell what you have just done.
   b. What organ does the handle enter?
   c. Push the stomach to the frog's left and draw it in this position to show its shape and relative size.
6. Extending from the stomach is a tubular structure of considerable length, the *small intestine*. At the lower end of the small intestine the tube becomes larger and then disappears between the two thighs. This last part of the tube is called the *cloaca* or *large intestine*.

   Draw the small and large intestines.
7. Between the stomach and the first loop of the small intestine is a thin pink body, the *pancreas*, which is a very important digestive gland.

   Draw the pancreas.
8. Label heart, lungs, liver, stomach, small intestine, large intestine, bile sac, pancreas.
9. Push the small intestine to one side and find two red bodies on either side of the spinal column. These bodies are the kidneys. The kidneys remove the *nitrogenous waste* (*urea*) from the blood.

   Make a sketch of the kidneys twice the natural size.

82. Habits of frogs. — There are many kinds of frogs, differing from one another considerably in size and color; but all frogs live in places where water is more or less abundant. Frogs are often found either on the banks of ponds and streams, or floating on the surface of the water with only the tip of the nose above water (Fig. 78). In color they usually resemble their surroundings rather closely, and so secure a certain degree of protection from fishes, snakes, birds, and man, which are their more common enemies. When pursued, they quickly disappear beneath the water and often bury themselves in the mud at the bottom until the need of air compels them to return to the surface. Late in the autumn they burrow in the mud and remain there until the following spring. The more or less pointed snout of the frog, its slippery skin, its long, muscular legs, and its webbed feet all adapt the animal for rapid swimming through the water.

FIG. 78. — Frogs in their habitat. Four frogs are shown; in the middle of the picture a black snake is preparing to seize the frog. (Part of an exhibit at American Museum of Natural History.)

83. Food, food-getting, and digestion. — Frogs feed upon insects, fish, and other frogs, and even birds have been found in their stomachs. Insects are caught by the aid of the slimy tongue, the tip of which can be quickly thrust out of the mouth and then drawn back again with the insect adhering to it (Fig. 79). The tiny teeth that are found on the upper jaw and the two large teeth in the roof of the mouth are useful only in preventing the escape of the prey from the mouth. Hence the food is swallowed without being chewed, and after passing down the short gullet it enters the tubular stomach (Fig. 80), where it is partially digested by ferments (**P. B., 53**) secreted by certain cells found in the lining of this organ.

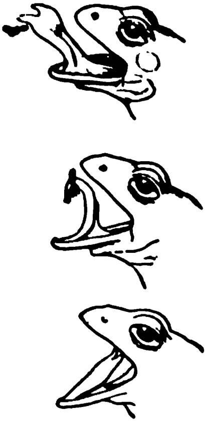
Fig. 79. — The method by which a frog secures insects.

When the food leaves the stomach, it enters the coiled small intestine where the process of digestion is continued by the bile secreted in the liver and the pancreatic juice prepared in the pancreas.[1] As the digested food slowly moves along the small intestine, it is absorbed by the capillaries (**84**) in the walls of this tube and so may be carried by the blood to the various cells of which the body is composed. Digestion not only prepares the food for absorption, but as in plants (**P. B., 51**) or in the fish (**98**), makes it ready to be used in the cells either for growth and repair or for the production of energy.

84. Blood and circulation. — The blood of the frog, when examined under the microscope, is seen to consist of two kinds of cells (the *red* and *white corpuscles*) which are floating in a liquid known as *plasma.* The plasma consists largely of water and the digested foods that have been absorbed from the alimentary canal (**83**).

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[1] Both of these digestive fluids are carried to the intestine by ducts.

As in the fish, the circulatory system consists of the heart and three kinds of blood vessels; namely, arteries, veins, and capillaries. The heart is located in the body cavity just back of the head and consists of two auricles and a ventricle (Fig. 81), instead of a single auricle and ventricle as in the fish (Fig. 100). As might be expected, this makes necessary other differences in the circulatory system of the frog. In the fish we shall see that there is only one stream of blood flowing into the heart, while in the frog there are two. One stream enters the heart from the various organs of the body which the blood has supplied with food and oxygen, and from which the blood has received carbon dioxid. The second blood

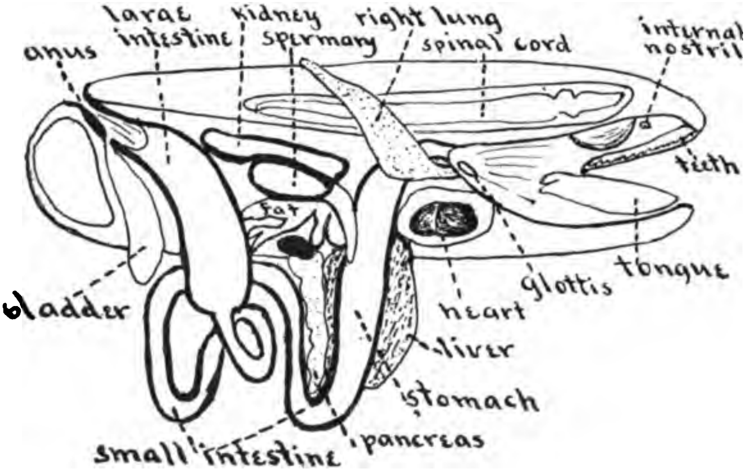

FIG. 80.—Internal organs of the frog.

stream comes from the lungs where the blood has given off the carbon dioxid and received a fresh supply of oxygen. The right auricle receives the blood brought from the body in three large veins, while two small veins carry into the left auricle the blood from the lungs.

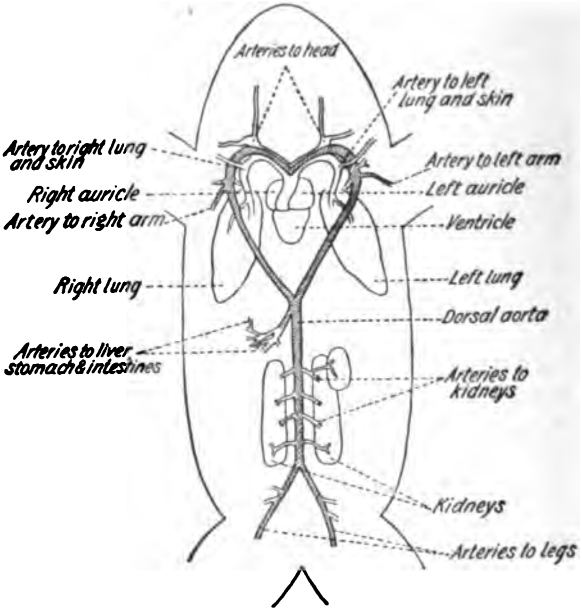

FIG. 81. — Arteries in the circulation of the frog.

The blood from both auricles now flows into the single ventricle, which then contracts and pumps the blood into a large artery. Certain branches carry the blood having the larger amounts of oxygen (*i.e.* the blood from the lungs) to the head, trunk, legs, and other organs of the body, while other branches carry the blood just received from the body, with its larger amount of carbon dioxid, to the lungs and the skin.

In the capillaries which connect the arteries and veins in every part of the body (Fig. 82) all the changes in the composition of the blood take place, since their thin walls permit the food materials and oxygen to enter the cells and the wastes from the cells to enter the blood.[1] The capillaries in the lungs likewise permit the interchange of oxygen and carbon dioxid.

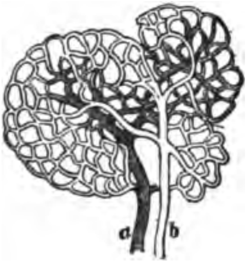

FIG. 82. — Network of capillaries connecting an artery and a vein.

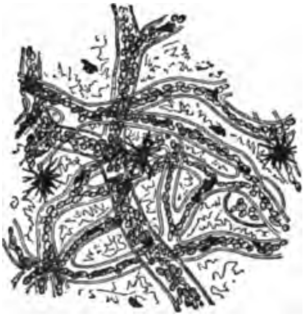

FIG. 83. — Capillaries in web of frog's foot.

85. Respiration and the liberation of energy. — The walls of the frog's lungs contain a network of capillaries, and in these thin-walled tubes the red corpuscles absorb the oxygen that is forced into these sacs by the upward movement of the floor of the mouth. As we have seen, the blood with a fresh supply of oxygen flows from capillaries of the lungs into veins and so finally into the left auricle and thence into the ventricle. Here it tends to become somewhat mixed with the blood from the right auricle which has just returned from the body. However, the structure of the heart and the arteries is such that the blood that has come from the lungs with a larger supply of oxygen is sent out by arteries to all parts of the body.

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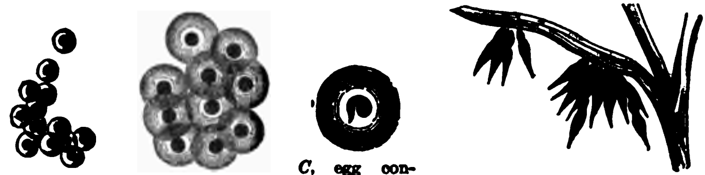
[1] A tadpole's tail is excellent for demonstrating the blood current. Wrap a tadpole in wet cloth or cotton and support it so that the tail can be placed between two glass slides on the stage of the microscope. The space between the two slides should be kept filled with water. The movement of the corpuscles through the margin of the tail should be examined with the low power of the microscope (Fig. 83).

In the capillaries the oxygen is absorbed by the cells. Oxidation of the food and protoplasm takes place and energy is thereby released, which enables the frog to carry on locomotion, secure its food, and perform all its destined tasks. The carbon dioxid and other wastes produced by oxidation pass through the capillary walls into the blood and, as we have seen, are carried back to the heart and then to the lungs, where carbon dioxid is excreted. Other wastes are excreted by the kidneys.

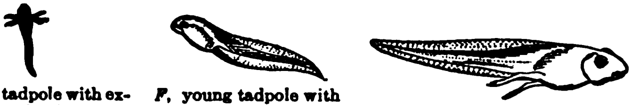
The skin of the frog is likewise permeated by a network of capillaries so that it acts as do the gills of fishes in absorbing oxygen from the water and in giving off carbon dioxid. While the frog is buried in the mud during the winter it breathes entirely through the skin. So much does the frog depend on the skin as a breathing organ that even in summer, if the skin becomes dry so that air cannot be absorbed, the frog dies.

86. Reproduction and life history. — In the animals studied thus far we have found special organs devoted to the process of reproduction, namely, ovaries for egg production in the female and in the male spermaries that form the sperm-cells. Before the egg-cells can develop into embryos each must be fertilized by a sperm-cell. All the facts we have just stated apply equally well to the frog.

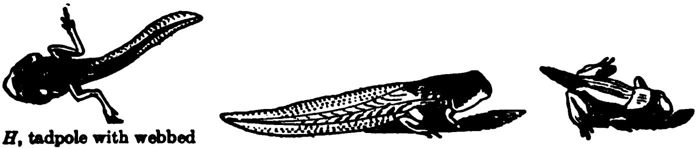
Frogs' eggs are deposited in springtime in masses that



A, eggs before they are laid **B**, eggs after they are laid **C**, egg containing young tadpole **D**, young tadpoles attaching themselves to a plant

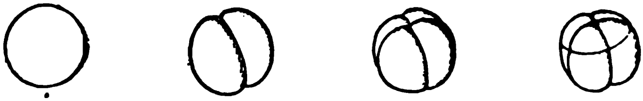


E, young tadpole with external gills **F**, young tadpole with internal gills **G**, young tadpole with hind legs

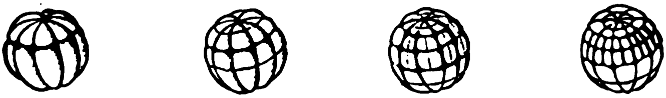


H, tadpole with webbed feet **I**, tadpole with legs and arms **J**, young frog

FIG. 84. — Life history of frog.



A, one-celled stage **B**, two-celled stage **C**, four-celled stage **D**, eight-celled stage



E, sixteen-celled stage **F**, thirty-two celled stage **G**, sixty-four celled stage **H**, many-celled stage

FIG. 85. — Cell division in a frog's egg.

float on the surface of the water[1] (Fig. 84, *B*). Each fertilized egg is a small sphere, black on its upper surface and white beneath, and inclosed in a gelatinous covering. The warmth of the sun causes the one-celled egg to divide vertically in half to form the two-celled stage (Fig. 85, *B*) and the process of division continues until the egg consists of many cells (Fig. 85, *H*). Food for the development of the embryo is stored in the egg.

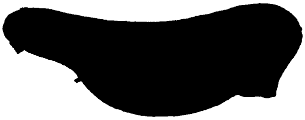


FIG. 86. — Embryo of frog.

The many cells of the egg gradually become different in character and so form the various organs of the embryo (Fig. 86). Soon after hatching, the young of the frog, known as *tadpoles*, secure their food by sucking in tiny water plants found on the surface of plants and stones (Fig. 84, *D*). Tadpoles resemble fishes in having gills for breathing, a heart with two chambers instead of three, and a tail for locomotion. At first the gills are on the outside of the body (Fig. 84, *E*), but later four pairs of internal gills are formed, and the external gills are absorbed. The animal increases in size, the hind legs appear, and the arms are formed beneath the skin. Meanwhile the lungs are being developed, the heart becomes three chambered, the legs grow larger, arms appear, and finally the gills and the tail are completely absorbed. The tadpole now leaves the water, since it is an air-breathing animal. This succession of changes after hatching from the egg is known as a *metamorphosis*.

87. Relatives of the frog. — Much like the frog in structure and life history is the common garden toad. Toads, however, in their adult stage cover themselves more or less with dirt in the daytime, and come out at night to feed upon insects, which constitute their sole food. Instead of having a smooth, slimy skin, as does the frog, a toad's skin (Fig. 87) is dry and covered with elevations commonly known as "warts." These elevations contain cells which secrete an irritating substance that protects the toad from animals that would prey upon it. There is no foundation, however, for the popular notion that the warts of human beings are ever caused either by toads or frogs.

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[1] If possible eggs in different stages of segmentation should be secured, preserved in 5 per cent formalin, and used for demonstration.

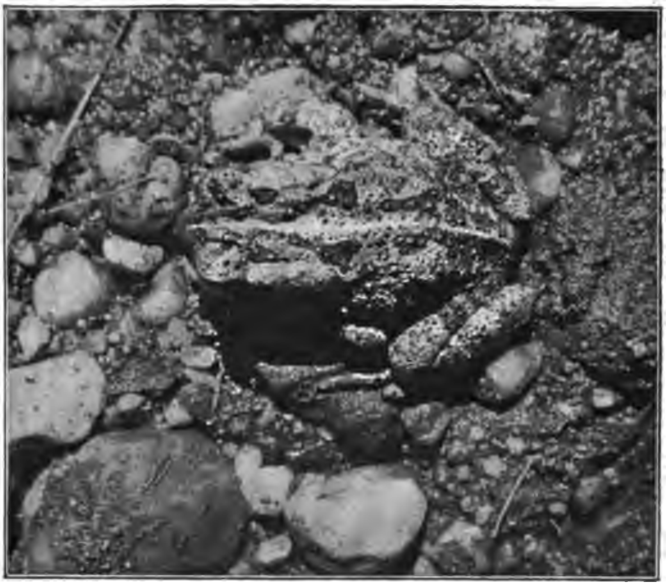

Fig. 87.—The toad. Note its resemblance to its surroundings, whereby it is likely to be protected.

In springtime toads seek the water in which to breed. The eggs, covered with a gelatinous substance are laid in long strings instead of in masses, as was the case with frogs. The development and life history of the toad is much the same as in the case of the frog. As soon as metamorphosis is complete, the little toads leave the water and often are found considerable distances away from water.

Less like the frog, at least in its adult stage, are the salamanders and newts (Fig. 88). These are found in damp places or in water and are often called "lizards," by those who do not know that a lizard has scales, claws on its feet, and breathes throughout its life by means of lungs. Some of the relatives of the frog, even after they have developed lungs, retain gills throughout their life (Fig. 89).

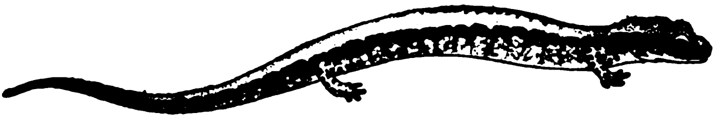

FIG. 88. — The newt.

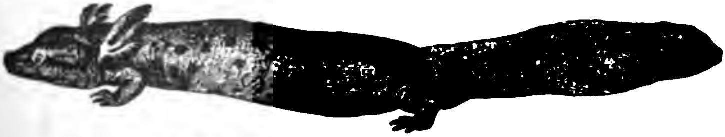

FIG. 89. — A mature amphibian (Necturus) with external gills.

Because of the ability of the animals described in this chapter to live both on the land and in the water, they are called the ***amphibia***, from Greek *amphi* = both + *bios* = life.

88. Economic importance of the amphibia. — None of the amphibia, so far as is known, are harmful to man. On the contrary, all of them are more or less useful because of the insects that they devour. This is especially true of the garden toad. It has been estimated by one author that a toad in a garden is worth nearly twenty dollars a year on account of the cutworms and other injurious insects that it destroys. In France the gardeners even buy toads to aid them in keeping obnoxious insects under control." —HEGNER'S "College Zoölogy."

Frogs, in addition to their value as insect destroyers, are also of some value to man as food. It is said that in the United States about $50,000 is obtained annually by the frog hunters for their catch, and frog farms are now profitably maintained in several states. Frogs are also used as fish bait.

CHAPTER IV

FISHES

89. What is a fish?—"A fish is a backboned animal which lives in the water and cannot ever live very long anywhere else. Its ancestors have always dwelt in water, and likely its descendants will forever follow their example. So, as the water is a region very different from the fields or the woods, a fish in form and structure must be quite unlike all the beasts and birds that walk or creep or fly above ground, breathing air, and being fitted to live in it. There are a

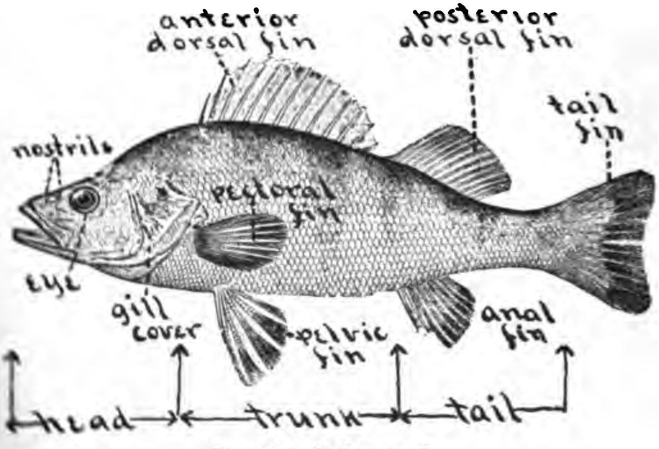

FIG. 90.—Yellow perch.

great many kinds of animals called fishes, but in this all of them agree: all have some sort of a backbone, all of them breathe their life long by means of gills, and none have fingers or toes with which to creep about on land."[1]

90. The regions and appendages of a yellow perch. — Study Figure 90 and notice that the body of the yellow perch is divided into three regions; namely, *head*, *trunk*, and *tail*. Unlike the body of many animals, no neck is present, and the head, therefore, is joined directly to the trunk. The line of union of head and trunk is the posterior[2] margin of movable flaps, called the *gill covers*, on the sides of the head. Just behind or posterior to the gill cover on each side of the trunk of the fish is a paddle-like organ called the *pectoral fin*. On the ventral surface, below the pectoral fins, is a second pair which are known as the *pelvic fins*. The pectoral and pelvic fins are together known as the *paired fins* of the fish. Besides these this animal has several *unpaired fins*, which we shall now locate. On the dorsal surface notice two *dorsal fins*, one behind the other, which project upward. Below the posterior dorsal fin, on the ventral surface, is another single fin called the *anal fin*. The tail region is considered to begin just in front of the anal fin, since in the fish the body cavity that contains the important organs of digestion, circulation, and reproduction ends at this point (Fig. 98). The anal fin, therefore, and also most of the posterior dorsal fin, are attached to the tail region. At the posterior end of this third region is the broad forked *tail fin*.

91. Regions and appendages of a goldfish. — Laboratory study.

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[1] Jordan's "Guide to the Study of Fishes," Vol. I, p. 3.
[2] The meaning of each of these terms is explained in 6.

Materials: A living goldfish in a battery jar for each two students. Goldfish may be kept indefinitely in a glass jar with green water plants; the latter supply the fish with food and oxygen. Perch, and if possible the heads of large fishes like the cod, should be obtained, preserved in formalin (5 per cent), and then thoroughly washed in running water for twenty-four hours before they are used; material treated in this way loses its fishy smell, and may be kept in the formalin solution year after year. A fish skeleton is also needed for demonstration. The Jung charts of the external and internal structure of the perch are useful.

Observe a living goldfish and compare it with Figure 90.

1. Name the regions of its body and state, with reference to gill cover and fins, where each region begins and ends.
2. Name and locate all the organs you find on the head.
3. What paired and what unpaired fins are found on the trunk? Using the terms anterior, posterior, dorsal, ventral, median, and lateral, locate each of these fins.
4. Name and locate the fins attached to the tail region of the body.
5. Make an outline sketch about five inches long of the side view of a living goldfish to show the shape and relative size of the three regions, the position and shape of the organs of the head and of the various kinds of fins. Label the regions and the organs that you have drawn, in a manner similar to Figure 90.

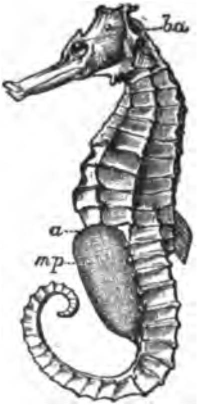

FIG. 91.—Sea horse.

92. Some differences in the form of fishes. — One can usually tell whether or not an animal is a fish; but in some cases this is extremely difficult. Who would think, for instance, that such animals as the sea horse (Fig. 91) and the pipefish (Fig. 92) would be

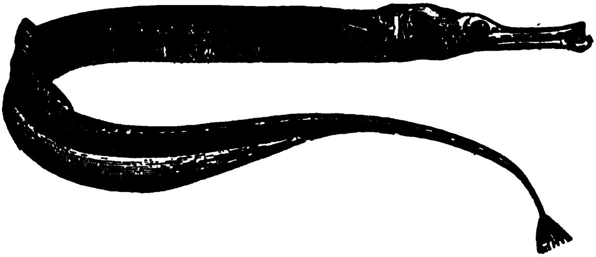

Fig. 92. — Pipefish.

classed with the perch and goldfish? Yet such is the case, since careful study has shown that these forms have all the characteristics mentioned in **89**.

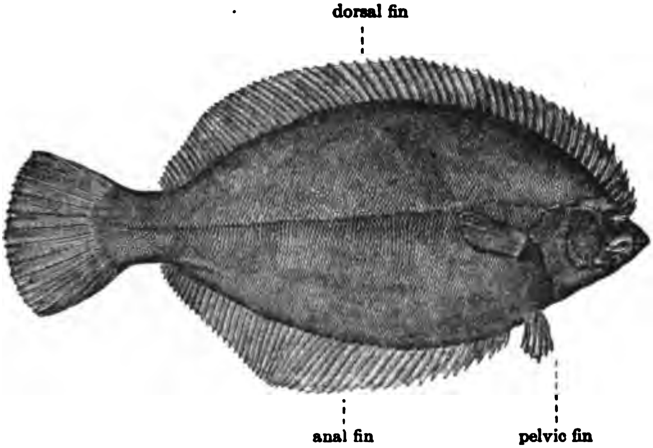

Fig. 93. — Flounder.

It is evident that the goldfish and perch have bodies that are considerably longer than they are wide or deep, and this is true of most of the common fishes. In the group of fishes known as the eels this elongation is so marked that they look more like snakes than they do like fishes. But the eels are not the only fishes that show a striking development in one dimension. The flounders, for example (Fig. 93), exhibit a notable growth in a dorso-ventral direction. So far has this been carried that the fish is unable to retain a vertical position, and consequently lies on one of its sides. The eyes, which, in very young flounders, are situated like those of the goldfish on either side of the head, by a twisting of the bones of the skull, both come to lie on the same side of the head. Otherwise, as may be seen, one of the eyes would rest on the sand or mud, when the animal is on the sea bottom. Fishes like the skates and sting rays (Fig. 94) have also a much flattened body, but these animals have

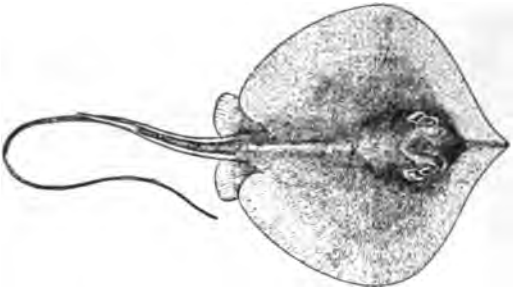

FIG. 94.—Sting ray. (Jordan and Evermann. Courtesy of Doubleday, Page & Co.)

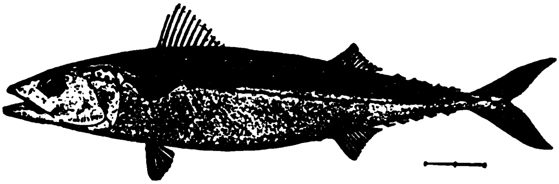

FIG. 95.—Mackerel. (Jordan and Evermann. Courtesy of Doubleday, Page & Co.)

attained this condition by growth from side to side, instead of dorso-ventrally.

93. Some differences in the fins of fishes. — We have seen that the goldfish has one dorsal fin, the perch two, and that both fishes have a single anal fin. A glance at Figure 108 will show that the codfish has three dorsal fins and two anal fins. Dorsal and anal fins vary not only in number, but in extent. In some fishes they are very short, as in the mackerel (Fig. 95), while in the flounder (Fig. 93) these fins extend nearly the whole length of the dorsal and ventral surfaces.

Most common fishes possess both pectoral and pelvic fins, but in the eels (Fig. 96) the pelvic fins are entirely wanting and the pectoral fins are very small. The paired fins vary in position as well. In the perch, for example (Fig. 90) the pelvic fins are immediately below the pectorals, while in the cod (Fig. 108) they are anterior to the pectoral fins, and in the salmon (Fig. 107) they are even farther back on the body than in the goldfish.

FIG. 96. — Eel. (Jordan and Evermann. Courtesy of Doubleday, Page & Co.)

94. Adaptations for swimming. — Laboratory study.

1. Carefully watch for a time a goldfish when it is swimming around in a large battery jar or aquarium.
   a. Which of the three regions of the body is principally used in pushing the animal forward?
   b. Describe the movements of this body region.
2. Which of the paired fins are used in swimming? De-

scribe their movements. State whether or not you see the fish swim backward.

3. If the goldfish strikes backward with the fins against the water, would the fish tend to move forward or backward?
4. Since the goldfish moves the fins both backward and forward in the water, in which direction must it strike the harder and more swiftly if it wishes to swim forward?

5. (Optional.) Suppose the fish strikes backward harder with the fins on the right side than it does with those on the left side, how would the direction of its motion be affected?
6. (Optional demonstration.) Place the largest goldfish you can get, in a sink or other large receptacle full of water. Get the fish to swim continuously and rapidly, but not so rapidly that the pupils are unable to see the paired fins.
   - *a.* What have you seen that leads you to think that the goldfish does not use the paired fins in rapid swimming?
   - *b.* What parts does the animal use to drive itself rapidly through the water?

7. Why are the broad, flat surfaces of the fins of advantage to the fish in swimming?
8. Study the anterior, dorsal fin of a perch or other fish. Notice that it is composed of stiff *fin rays* and of thin *connecting membrane.* Alternately spread out and close the fin, and bend each of the materials of which it is composed. Now describe the structure of this fin.
9. Examine carefully each of the fins of a goldfish.
   - *a.* State whether or not each consists of fin rays and connecting material.
   - *b.* What disadvantage to a goldfish in swimming would result from the absence of the rays in a fin?
   - *c.* State the relative difference in the size of a fin when it is spread open and when it is closed.
   - *d.* What would be the disadvantage if the open fin had no connecting membrane?

95. The locomotion of fishes. — Many fishes, like the goldfish and perch, are able to maintain a given position in the water while at rest. This is made possible by means of an internal organ known as the *swim bladder* (Fig. 98). The swim bladder may be compressed, permitting the fish to sink, or it may be expanded, causing the animal to rise. Since, therefore, the fish is poised in a liquid medium, it is only necessary to overcome the resistance of the water about it in order to move in any given direction. This resistance is more easily overcome, first, because the head is somewhat pointed like the prow of a boat, secondly, because the overlapping *scales* point backward, and third, because the whole body is covered with a slimy *mucus*.

One who is at all familiar with a canoe knows that it is impossible to propel it by the use of a slender rod. One must have a paddle with the lower end broad and flat so that sufficient force may be exerted against the water to propel the canoe. Now, in swimming, the fins of a fish act more or less like paddles. Their broad, flat surfaces press against such an amount of water that the fish is enabled to exert enough force to push its body in any desired direction.

If one watches a goldfish swimming slowly about in an aquarium, one would think that the paired fins, especially the pectoral fins, were the important swimming organs. But careful experiments have shown that this is not the case. When the goldfish has occasion to move more rapidly, the paired fins are not used at all, but are pressed close to the sides, the body being driven through the water by the movement of the tail and tail fin. The paired fins, together with the dorsal and anal fins, seem to be used principally in steering the fish. The energy necessary for swimming is developed in the powerful muscles of the tail and trunk.

96. Adaptations for food getting. — Laboratory study.

1. Open the jaws of a fresh or of a preserved fish. (Fish of large size, *e.g.* cod, should be used if possible, the jaws being held wide open with pieces of wood.) Look for teeth on the jaws and the roof of the mouth.
   - *a.* State the location of the teeth and give some idea of their number.
   - *b.* Rub the fingers gently back and forth over the teeth. Do they point backward or forward? How do you know?

     Describe any other characteristics of the teeth.
   - *c.* Of what use would the teeth be in catching other fish for food?
   - *d.* Why would the shape of the teeth make them of no use in grinding food?
2. Drop some fish food into a jar containing living goldfish.[1] Describe all the movements that you see the fish make while feeding.

97. Food and food getting among fishes.—Unlike plants, fishes cannot make their food from materials found in the water, air, and soil, but must secure it ready-made from plants or other animals. The goldfish, for example, depends largely on vegetable food, while the cod[2] and the perch for the most part feed upon other animals smaller than themselves. Since these fishes must catch and hold their prey, their jaws are provided with many sharp teeth that point backward, and so prevent the escape of any active animal which may have been caught. The cod, as you may have seen, has teeth in the roof of the mouth and in the throat in addition to those found on the jaws, thus making more secure its hold upon the unfortunate denizen of the deep that it has seized.

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[1] If none of the fish eat readily, this experiment should be deferred.

[2] "The cod is omnivorous, and feeds upon various kinds of animals, including crustaceans, molluscs, and small fishes, and even browses upon Irish moss and other aquatic vegetation. All sorts of things have been found in cods' stomachs, such as scissors, oil cans, finger rings, rocks, potato parings, corn cobs, rubber dolls, pieces of clothing, the heel of a boot, as well as other new and rare specimens of mollusks and crustacea." — JORDAN and EVERMANN, "American Food and Game Fishes."

Certain fishes depend on minute forms of plants and animals, and therefore some means is needed by which the water taken in with the food may be gotten rid of while at the same time the food is retained. Hence, fishes are provided with a straining apparatus which permits the water to escape when the mouth is closed, and retains within the mouth the minute forms of life that it has secured. Of this adaptation for food getting, we shall learn more in our study of the gills.

Most of the fishes that prey on other animals secure their victims by dint of their speed; but one form of fish, called the "deep sea angler" (Fig. 97), has upon the dorsal part of the head a bulbous projection, the tip end of which is luminous. This bright light attracts other fishes, and when they approach near enough, the " angler " makes a quick dash, closes its big jaws upon the too curious individual, and so

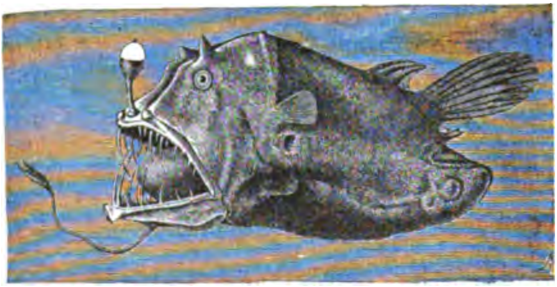

FIG. 97. — Deep sea angler.

secures food. But whatever a fish feeds upon, and however it secures its food, it is evident that plants and other animals must furnish the food substance required to make living matter, and so provide for growth and repair of the cells, and also furnish the fuel needed to develop the energy necessary for the various activities of the fish.

98. Digestion and digestive organs. — We have seen in plants (P. B., 63, 70, 74) that digestion may take place in any living cell where food is stored or manufactured. Hence plants have no special part devoted to digestion. In fishes however, it is quite different, since a portion of the body, known as a digestive system, is devoted to preparing the food for absorption and use. This digestive system consists of a food tube known as the *alimentary canal* and certain masses of cells known as *digestive glands.*

When the fish swallows food, this passes from the mouth cavity into a short tube, called the *gullet,* and thence into a comparatively long wide *stomach* (Fig. 98), which in the carp extends half the length of the body cavity. From the stomach extends the *small intestine,* which turns upon itself

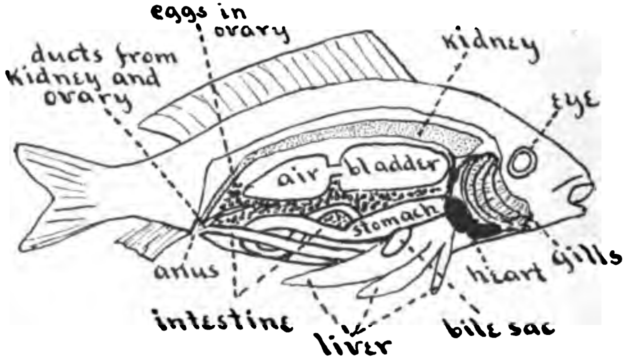

FIG. 98. — Internal organs of a fish. (Carp.)

several times, thus forming a coil, the posterior end of which finally opens to the exterior just in front of the anal fin.

In the inner lining of the stomach and intestine are special cells which make up digestive glands. These have the power to manufacture digestive ferments (**P. B.**, 53), which are forced out into the alimentary canal when food is present. As in plants, these ferments dissolve the foods and make them ready for use in the body. In addition to the digestive glands in the lining of the alimentary canal there are glands outside the digestive tube. One of these is the *liver* (Fig. 98), which secretes bile. This is carried to the intestines by a tube called the bile duct. In the liver is a sac (*bile sac*) (Fig. 98) which holds any excess of bile. When the food has been digested it is absorbed by thin-walled blood vessels found in the lining of the alimentary canal, and so passes into the blood to be distributed around the body.

99. Blood and circulation. — Instead of ducts and sieve tubes (**P. B.**, Figs. 14, 15, 16) as in the seed plants we studied, the fish has *blood vessels* to distribute digested foods to various parts of the body. In addition to these the fish possesses a *heart* (Fig. 99), which aids in pumping or forcing the blood through blood vessels, thus keeping it in constant motion. The blood vessels are of three kinds; namely, *arteries, capillaries, and veins*. The arteries have muscular and elastic walls which contract and so aid the heart in forcing the blood along its course. The arteries always carry the blood away from the heart, and they subdivide into smaller and smaller tubes. At the ends of the smallest arteries are tiny, short, thin-walled blood vessels, known as capillaries. Capillaries permit the digested food to osmose through their walls into the adjacent cells, and, in turn, absorb waste matters from the cells.

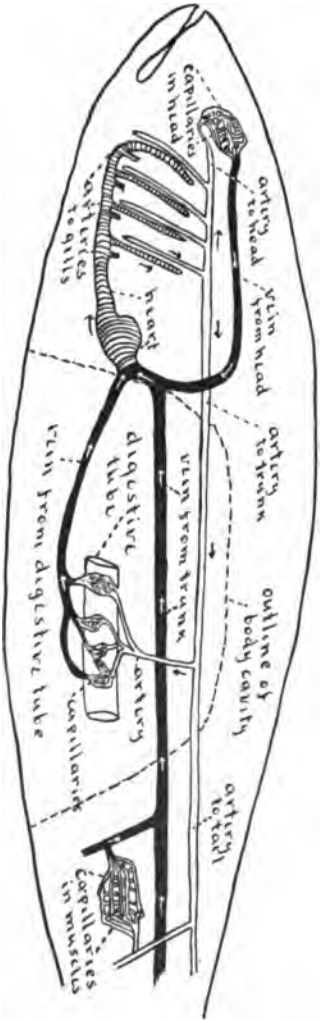

Fig. 99.—Diagram of the circulation of a fish.

The blood passes from the capillaries into the veins,[1] which are thinner-walled than the arteries. These veins carry the blood back to the heart. The heart (Fig. 100) consists of two principal parts; a thin-walled *auricle* which receives blood from the veins, and a thick-walled, muscular portion called the *ventricle*, which forces the blood out into the arteries.

100. Adaptations for breathing. — Laboratory study.

1. Raise the gill covers of a preserved fish and find the gills. Carefully separate the gills with the forceps. How many gills are present on each side?
2. The openings between the gills are called *gill clefts*. Gently push a thin strip of wood or the forceps through one of the gill clefts as far as you can.
   a. In what cavity do the forceps or strip of wood appear?

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[1] This is true of all organs of the fish, excepting the gills. See 101.

b. Describe the situation of the gills with reference to the mouth cavity.

3. Hold the preserved fish with its mouth upward and carefully pour water into the mouth opening. Where does the water come out?

4. Place a gill that has been removed from a fish (a salmon if possible) in a watch glass and cover it with water. Find the following parts: (1)a soft part made up of slender divisions called *gill filaments.* (2) a curved part to which the gill filaments are attached, known as the *gill arch*, and (3) projections on the side opposite the gill filaments which are known as *gill teeth* or *rakers.*

a. Is the gill arch relatively hard or soft compared to the filaments?

b. Are the gill teeth or rakers relatively hard or soft?

c. Look again at the perch and state whether the rakers are found on the side of the arch nearest to the mouth cavity or on the opposite side.

What is the use of the gill teeth when the fish takes in a mouthful of water containing food, and does not wish to swallow the water?

d. Make a sketch (about four inches long) of a gill to show the shape of the whole and the structure of a small portion. Label gill arch, gill filaments, gill rakers.

5. The gill filaments contain thin-walled blood vessels (capillaries) which are separated from the water by a thin membrane. The heart forces the blood into certain arteries that carry it to the capillaries in the gills and thence blood passes back to the body through another set of arteries. (Fig. 100.) Bearing in mind that breathing is essentially the same in animals as in plants (**P. B.**, **82**), —

a. What gas will the blood bring from the body to be given off in the gills in the process of breathing?

b. What gas is taken up by the blood in the gills to be carried around through the body?

c. How are the gill filaments (as stated above) fitted by structure to permit this interchange of gases?

d. How are the delicate gill filaments protected from injury?

6. If the same water remained on the gills for some time, what change would occur in the amount of oxygen in the water? in the amount of carbon dioxid in the water? Why, then, is it necessary that a current of water should pass over the gills?

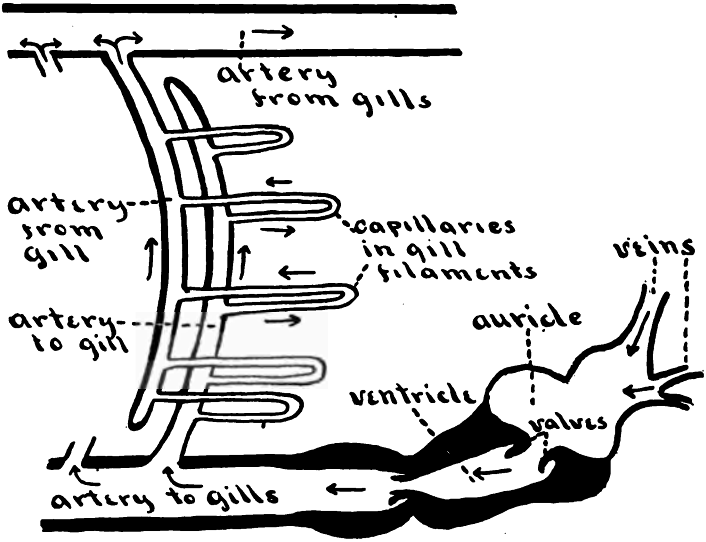


Fig. 100. — Diagram of the circulation of blood in the gill of a fish.

7. Describe the movements of the jaws and gill covers of a living goldfish when it is breathing. (If the fish has been in a jar of water without green plants for some time, these movements will be more pronounced.)
8. Watch the fish as it opens its mouth.

a. Is the size of the mouth cavity now greater or less than it was when closed?

b. Why does the water now enter the mouth? (The inward movement of the water may be demonstrated

more easily if some powdered carmine is stirred into the water.)
  - *c* What will the incoming current of water bring to the gill filaments?

9. Watch the fish as it closes its mouth.
  - *a.* Is the size of the mouth cavity now greater or less than it was before?
  - *b.* What forces open the gill covers?
  - *c.* What will the current of water carry away from the gill filaments?

101. Respiration and the liberation of energy. — We have just seen that when the goldfish takes in a mouthful of water and then closes its mouth, the water is forced over the gills, thus bringing oxygen to the filaments. The capillaries in the filaments absorb the oxygen, and the blood then passes on into other arteries which carry it all over the body of the fish. In the capillaries at the ends of the smallest arteries the oxygen passes into the cells as does the food. Now what becomes of the oxygen?

As in plants (**P. B.**, **80**), the oxygen unites with elements in the foods and in the protoplasm of the cells and produces oxidation and liberation of energy, which gives the fish the power to contract its muscles and so to push against the water with its tail and tail fin, thus propelling the animal in any direction, or to open its jaws and shut them on another fish, thus securing food. In fact, all the work that the fish performs is made possible through the burning of its foods or protoplasm by the oxygen.

Since the proteins, fats, carbohydrates, and protoplasm all contain carbon, when these are oxidized, carbon dioxid (CO_2) is formed as one of the waste substances. All the waste substances pass out of the cells, through the walls of the capillaries, into the blood, which passes on into the veins and back to the heart. The heart contracts and drives the blood loaded with carbon dioxid out into the arteries, which carry it to the capillaries of the gills (Fig. 100). Here the waste matters pass into the water, which is then forced out under the gill covers by the closing of the mouth.

102. Adaptations for sensation. (Optional.)

1. Study the eye of a goldfish.
   a. Describe its position, shape, and size relative to that of the head.
   b. Notice that the eye consists of a black center (the *pupil*) through which light enters the eye, and a colored *iris*. Add these features to the drawing of the goldfish (**91**, 5), and label each.
2. The nostrils lie in front of the eyes, and as they are small, a preserved fish head may help in locating them. (In the perch there are two on each side.)
   a. Show in your drawing the position, shape, and size of the nostril of one side and label.
   b. Gently probe the nostril of a preserved fish with a stiff bristle.
      (1) Do the nostrils open into the mouth or not?
      (2) Could the nostrils be used in breathing? Give reason for your answer.
      (3) Bearing in mind the common uses of nostrils of higher animals, state which of these is the probable function of the nostrils of a fish.

103. Senses of fishes. — Fishes are said to possess keen sight. The eyes, however, except in rare cases, are only fitted for seeing while in the water. These organs have no eyelids, so the fish always seems to be wide awake. The sense of smell is located in the nostrils, and since these do not open into the mouth cavity, this is the only function of the nostrils. The taste sense is said to be located in the outer skin. The fish has no external ears; it has, however, internal ears, but these are supposed to serve as balancing organs, rather than as organs of hearing. Fishes from which these internal ears have been removed are unable to maintain their equilibrium.

Some fishes have special organs that serve as tactile organs such as are found on the under side of the head of a cod (Fig. 108) and also on the head of bullheads (Fig. 101). Along each side of the body and tail of fishes is a series of little openings or pores which form what is known as the *lateral line* (Fig. 108). These organs are supposed to be principally organs of touch.

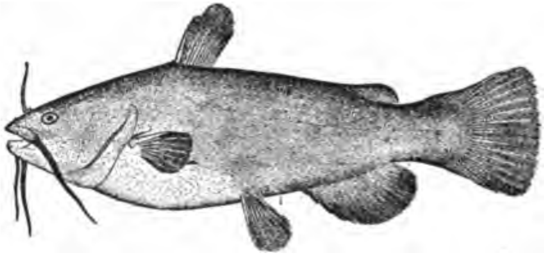
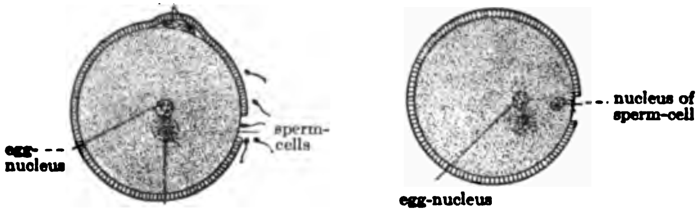


Fig. 101. — Bullhead. (Goode.)

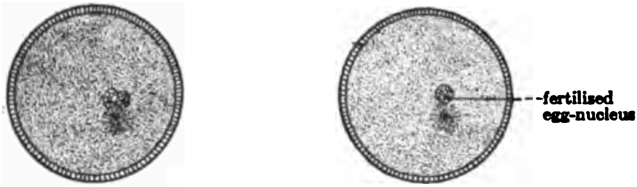
104. Reproduction and life history. — The flowers of seed plants are devoted to the production of seeds which, in turn, produce new plants of the same kind (**P. B.**, **83**). Likewise in fishes there are special organs the sole function of which is the production of new individuals. The organs of fishes which may be said to correspond in function to the stamens and pistils of flowers are the *ovaries* (Fig. 98) and *spermaries*. In the ovaries are produced many *egg-cells*, and the mass of eggs in the ovary of a fish is often called the *roe*. In order that an egg may develop it must first be *fertilized* by a *sperm-cell* from the spermary of a male fish. This process usually occurs in the water after the ripe eggs and sperm-cells have been extruded from the ovaries and spermaries of the parent fishes.

You will recall the fact that the pollen tube containing a sperm-nucleus makes its way into an ovule and that the



A, sperm-cell entering an egg-cell

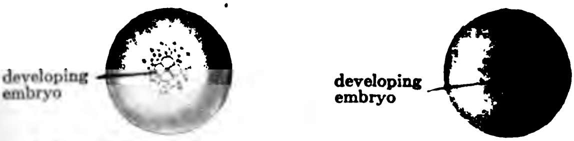
B, sperm-nucleus approaching the egg-nucleus



C, sperm-nucleus and egg-nucleus uniting

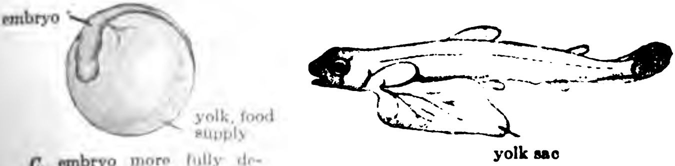
D, fertilized egg-nucleus

FIG. 102. — Fertilization of an egg.



A, four-celled stage of embryo

B, many-celled stage of embryo



C, embryo more fully developed

D, young fish with yolk still attached

FIG. 103. — Development of a fish egg.

sperm-nucleus is forced into the ovule and unites with the egg-nucleus; this is the process known as *fertilization* (**P. B.**, 91). In the case of fishes the sperm-cells swim to the eggs, and then force their way into the egg (Fig. 102, *A*).

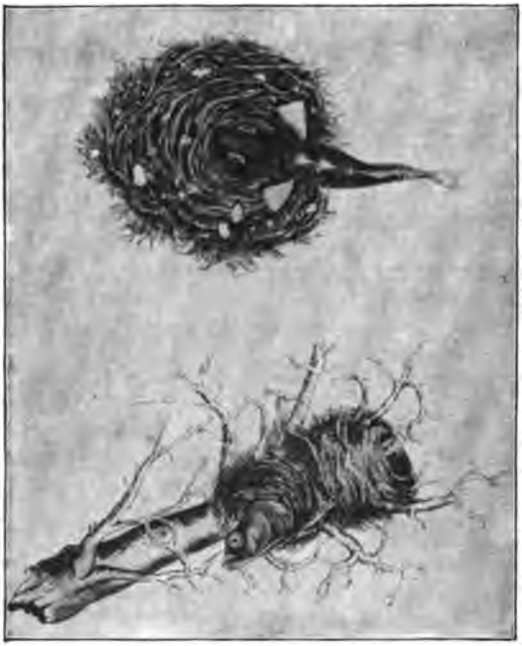


Fig. 104.—Nest of stickleback. Above, male entering nest with eggs; below, male depositing sperm-cells.

The nucleus of the sperm- and egg-cells then unite just as in plants (Fig. 102, *B*, *C*, *D*). The egg nucleus thus fertilized first divides, and then the cell body, and thus are formed two cells. Each of these cells in turn divides, and so four cells are produced (Fig. 103, *A*, *B*). The process of division continues until a many-celled organism is developed.

As the cells increase in number, they become different in character and form the various organs of the body. When the little fish first hatches, and begins to swim about, it often has attached to it some of the food substance (yolk) stored in the egg (Fig. 103, *D*). After this is used up, the young fish must secure its own food.

Most fishes do not take any care of their eggs or young, and in some cases the parents die soon after the eggs are laid and fertilized. In the case of the stickleback, however, the male fish makes a nest (Fig. 104) in which the females deposit their eggs. The male then extrudes sperm over the eggs. The male stays about the nest and guards the eggs and also the young sticklebacks when they hatch out.

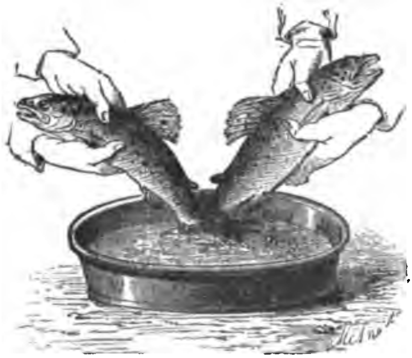


Fig. 105. — Artificial fertilization of eggs. (Coleman.)

105. Artificial propagation of fishes. — Since, as we have said, most kinds of fishes give no attention to eggs or young, enormous numbers of both eggs and young are eaten by other fishes; hence, only a small proportion come to maturity. For example, while a codfish lays 8,000,000 eggs, only about two of these eggs on the average come to maturity. Hence, in order to increase to any considerable extent the number of fishes, the eggs are artificially hatched. That is, the fish are caught when the eggs are ripe and the eggs are gently squeezed from the ovaries into the water (Fig. 105). Then some of the sperm-cells are similarly squeezed from the male fish and mixed with the eggs. This provides for fertilizing most of the eggs, which would probably not occur in nature. Special apparatus is devised for keeping the eggs supplied with fresh water until they hatch (Fig. 106). When the young are old enough they are fed for a time, then the *young fry*, are set free in the waters where more fish are desired. Millions of young fish are every year distributed by the government all over the United States to be placed in ponds, rivers, and lakes where the supply is deficient, or in the ocean along the shore.

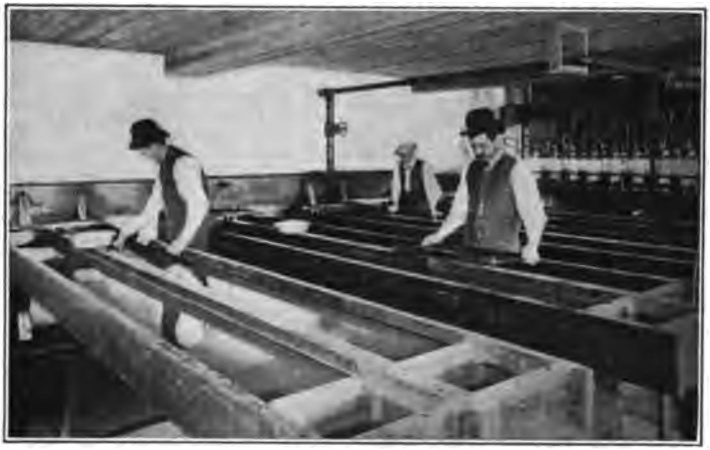


FIG. 106. — Interior of fish hatchery.

106. Economic importance of fishes. — From very ancient times fishes have formed a considerable part of the food of peoples that lived near bodies of water. The importance to man of fishes as a source of food can scarcely be overestimated. Unlike domestic animals, the fishes grow to maturity without any care on the part of man. The fisherman has only to provide the means to gather his harvest, while the herdsman must care for his flocks and herds the year round. Thus we see why fish are cheaper than other forms of flesh food.

While fish are most important to man as food, they have other uses. Thus, for instance, the menhaden are caught scarcely at all for food, but for the large quantities of oil extracted from them. The remainder of their bodies is used as fertilizer. It is estimated that about 3,000,000 gallons of oil and 1,000,000 tons of scrap, with a total value of $2,500,000 is obtained annually by American fishermen from this kind of fish. The oil extracted from the livers of cod forms a valuable food preparation for invalids, since it is said to be more easily absorbed and oxidized than any other known fat.

The great importance of fishes, however, is due to the fact that they furnish a cheap and wholesome food. Nearly all the parts of a fish are thus used. Not only is the flesh eaten, but also the eggs (roe). The swim bladders, too, of many fishes are made into isinglass which yields the highest grade of gelatin.[1] Fish are eaten not only in a fresh condition, but are also prepared in various ways. Among these methods of preservation are drying, smoking, pickling, and canning. Two of the more important fisheries are those of the salmon and the cod.

107. The salmon. — The salmon (Fig. 107) is doubtless the most important food fish of the world, and the Pacific salmon completely outclasses all other forms. The Atlantic salmon was once very abundant, but is gradually diminishing in numbers for reasons that will be mentioned later (110). "The salmon were made for the millions. The Siwash Indian eats them fresh in summer, dries them, or later on freezes them, for himself and his dogs in winter. The epicure pays for having the fresh fish shipped in ice to his table, wherever that table may happen to be. In mid-ocean, the great American canned salmon is often the best and only fish afloat. In the jungles of the Far East, in the frontier bazaar of the enterprising Chinese trader, it 'bobs up serenely' to greet and cheer the lonesome white man who is far from home and meat markets. Even in the wilds of Borneo its name is known and respected; and he who goes beyond the last empty salmon tin, truly goes beyond the pale of civilization. The diffusion of knowledge among men is not much greater than the diffusion of canned salmon; and the farther Americans travel from home, the more they rejoice that it follows the flag.

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[1] See article on isinglass in Cyclopedia.

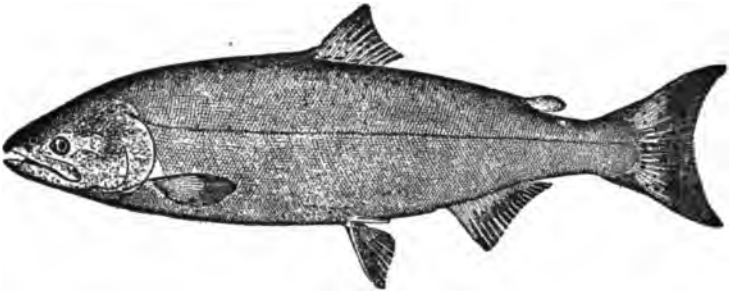

FIG. 107. — The Salmon. (Jordan and Evermann. Courtesy of Doubleday, Page & Co.)

"The common salmon of Europe, and also of Labrador and New England, was accounted a wonderful fish both for sport and for the table, until the discovery of the salmon millions of the Pacific Coast cheapened the name. To hold their place in the hearts of sportsmen, game fishes must not inhabit streams so thickly that they are crowded for room, and can be caught with pitchforks. Yet this once was true of the salmon in several streams of the Pacific Coast. The bears of Alaska grow big and fat on the salmon which they catch with the hooks that Nature gave them."[1]

The Pacific salmon are caught in the rivers that empty into the Pacific Ocean, such as the Columbia, Sacramento, and Yukon. The salmon reach their maturity in the ocean. When, however, the spawning time approaches, the salmon make their way in great numbers to the mouths of rivers like the Columbia and proceed up these streams, leaping seemingly impassable waterfalls in order to reach the headwaters. Here the sand is scooped out by the male, and the female salmon deposits her eggs and the male the fertilizing sperm-cells. The fertilized eggs are then covered with sand. The parent fish soon die; none ever reach the ocean again. After the eggs hatch, the young slowly float down the stream to the ocean to repeat the life of their parents.

It is when the fish are proceeding up the rivers that they are caught. Sometimes they are so abundant that the river seems to be choked with them. Salmon are shipped fresh in ice. Enormous quantities are also canned and smoked. The estimated value of the annual catch of Pacific salmon varies from $10,000,000 to $15,000,000.

108. The codfish. — Next in importance to the salmon, at least in the United States, is the cod (Fig. 108), for which the fishermen receive about $3,000,000. Other countries engaged in the cod fisheries are Newfoundland, Canada, Nor-way, Sweden, Great Britain, and France. The catch of cod for the world is estimated to be $20,000,000 annually. Codfish are found in the northern part of both the Atlantic and Pacific Oceans, but the Alaskan cod is not considered to be as fine a food fish as the Atlantic species.

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[1] From Hornaday's "American Natural History."

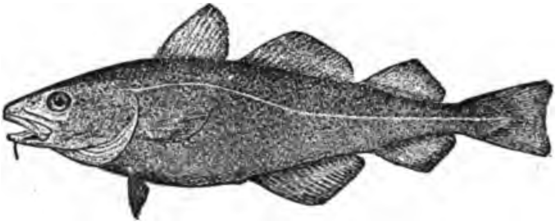

Fig. 108. — The codfish. (Goode.)

The cod is a deep water fish and is usually caught in from thirty to seventy fathoms (a fathom being six feet). Cod are caught off the coast of Newfoundland, and during the winter as far south as the Middle States. "From the earliest settlement of America the cod has been the most valuable of our Atlantic Coast fishes. Indeed the codfish of the Banks of Newfoundland was one of the principal inducements which led England to establish colonies in America, and in the records of early voyages are many references to the abundance of codfish along our shores. . . . So important was the cod in the early history of this country that it was placed upon the colonial seal of Massachusetts, and it was also placed upon a Nova Scotian bank note, with the legend 'Success to the Fisheries.' "[1]

The average weight of large cod is said to be from twenty to thirty-five pounds, depending on the locality. The average weight of small cod is twelve pounds. Jordan and Evermann state that cod weighing 75 pounds are not common, but that one was caught off the New England coast that weighed 211½ pounds.

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[1] From Jordan and Evermann's "American Food and Game Fishes." Every student of this fish work should read Kipling's "Captains Courageous" for description of the cod fisheries on the Grand Banks.

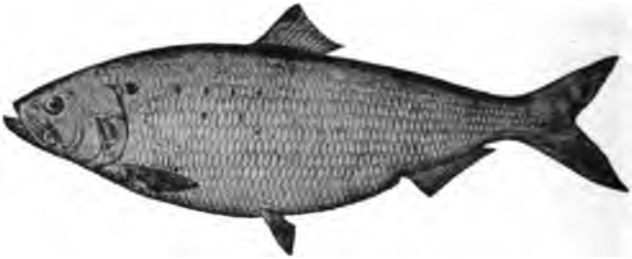

Fig. 109. — The shad. (Goode.)

Codfish are marketed fresh, pickled, salted, and dried. Oil and isinglass are also obtained from the cod.

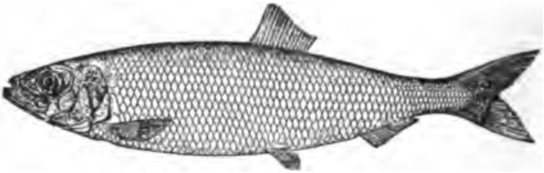

Fig. 110. — The herring. (Jordan and Evermann. Courtesy of Doubleday, Page & Co.)

109. Library study of other fishes. — (Optional.)

Consult Jordan and Evermann's "American Food and Game Fishes," Hornaday's "American Natural History," and special articles in Cyclopedias or other reference books, on one or more of the following fishes: mackerel (Fig. 95), sardine, shad (Fig. 109), herring (Fig. 110), white fish, smelt, bluefish, halibut, menhaden. Write in your notebook an account of the fishes selected for study, using the following topics as a guide: —

1. General appearance (size, color, general form).
2. Geographical distribution (that is, in what waters the fishes are found).
3. Food and feeding habits.
4. Method of capturing the fish.
5. Amount caught annually and its value in money.
6. Breeding habits and other general facts of interest.

If possible illustrate your composition with any drawings or pictures of the fish you are studying.

110. Visit to a fish market. — (Optional.)

In your notebook prepare an account of your visit to some fish-market, using the following topics as a guide.

1. Location of the fish market and the name of its owner.
2. Make a list of the various kinds of fish offered for sale.
3. State the kind of fish that sells at the lowest price per pound at this time of year.
4. State the kind of fish that is most expensive per pound at this season.
5. Name the kind of fish now sold in the greatest quantity.

111. Conservation of food fishes. — A story of reckless waste similar to that recorded in regard to the destruction of our forests may be duplicated here concerning the way men have exploited our abundant natural source of food, the fishes. The Atlantic salmon, which was once "the salmon," is now of comparatively little commercial importance. "Salmon were marvelously abundant in colonial days. . . . It is stated that the epicurean apprentices of Connecticut would eat salmon no oftener than twice a week. . . . There can be no doubt that one hundred years ago salmon fishing was an important food resource in southern New England. . . . But at the beginning of this century salmon began rapidly to diminish. Mitchill stated in 1814 that in former days the supply to the New York market usually came from the Connecticut, but of late years from the Kennebec, covered with ice. Rev. David Dudley Field, writing in 1819, states that salmon had scarcely been seen in the Connecticut for fifteen or twenty years. The circumstances of their extermination in the Connecticut are well known, and the same story, with names and dates changed, serves equally well for other rivers.

"In 1798 a corporation, known as the 'Upper Locks and Canal Company,' built a dam sixteen feet high at Millers River, 100 miles from the mouth of the Connecticut. For two or three years fish were seen in great abundance below the dam, and for perhaps ten years they continued to appear, vainly striving to reach their spawning grounds; but soon the work of the extermination was complete. When, in 1872, a solitary salmon made its appearance, the Saybrook fishermen did not know what it was."[1]

The Pacific salmon is rapidly disappearing also. "Naturally the salmon millions of the Pacific streams early attracted the attention and aroused the avarice of men who exploit the products of nature for gain. As usual, the bountiful supply begat prodigality and wastefulness. The streams nearest to San Francisco were the first to be depleted by reckless overfishing. . . . Regarding the conditions that in 1901 prevailed in Alaska, the following notes . . . are of interest: 'The salmon of Alaska, numerous as they have been and in some places still are, are being destroyed at so wholesale a rate that before long the canning industry must cease to be profitable, and the capital put into the canneries must cease to yield any return.'

"The destruction of the salmon comes about through the competition between the various canneries. Their greed is so great that each strives to catch all the fish there are, and all at one time, in order that its rivals may secure as few as possible. . . . Not only are salmon taken by the steamer load, but in addition millions of other food fish are captured, killed, and thrown away. At times, also, it happens that far greater numbers of salmon are caught than can be used before they spoil. . . . In many of the small Alaskan streams the canning companies built dams or barricades to *prevent the fish from ascending to their spawning beds*, and to catch all of them. In some of the small lakes, the fishermen actually haul their seines on the spawning grounds.

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[1] Jordan and Evermann's "American Food and Game Fishes."

"The laws passed by Congress to prevent the destruction of the Alaskan salmon fisheries are 'ineffective, and there is scarcely a pretense of enforcing them.' To-day the question is — will lawless Americans completely destroy an industry which if properly regulated, will yield annually $13,000,000 of good food? Will the salmon millions of the Pacific share the fate of the buffalo millions of the Great Plains? At present *it seems absolutely certain to come to pass*. . . . The time for strong, effective, and far-reaching action for the protection of that most valuable source of cheap food for the millions is *now!*"[1]

Many of the states have passed laws for the protection and conservation of game fishes such as trout and bass. The sportsmen have seen to this; and while it is desirable that these forms of wild life should be preserved and their number increased in all our waters, it is of much greater importance that the fishes which supply food for the millions should not be left to the mercy of such utterly selfish men as those responsible for the rapid depletion of the Atlantic salmon and the rapid decrease of the Pacific salmon.

It is necessary not only that the number of all fish desirable for food should be increased by means of artificial propagation as indicated in **105**, but also that wise laws governing the catching of fish should be passed and rigidly enforced. The United States government has done and is still doing splendid work in the artificial propagation and distribution of fishes through the agency of the thirty-nine fish-hatching stations of the Bureau of Fisheries, but has done little or nothing in the regulation of the fish industry. This has been left to the initiative of the states. Following are some of the regulations that many of the states have embodied in laws: (1) There must be no obstruction in rivers that would prevent fish from moving freely up and down streams either to spawn or to search for food. If dams are built, runways must also be constructed permitting the free passage of fish. (2) Fish must not be caught at the spawning season, otherwise the future supply is endangered. (3) No methods of fishing should be employed in which immature fish are caught or killed. Such methods are (*a*) exploding dynamite in the water, thus killing all kinds and sizes of fish indiscriminately; (*b*) catching fishes with nets the meshes of which are so small that immature fish are caught as well as mature; (*c*) wholesale and mechanical devices of catching fish such as the fishing wheel, for by this device the fish have no chance for escape. (4) Fishermen must not keep fish even when caught if they are undersized. (5) It should be illegal to destroy any food fish or use it for any purpose other than food.

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[1] Hornaday's "The American Natural History."

These laws are enforced by state fish and game wardens provided there is public demand for their enforcement. The necessity for the enforcement of these regulations will be obvious, not only in waters over which the states have jurisdiction, but also in the waters controlled by the United States government.

CHAPTER V

CRAYFISHES AND THEIR RELATIVES

112. A study of the crayfish. — Laboratory study.

A. *Regions*. — The body of the crayfish has two distinct regions. The dorsal surface and sides of the anterior region are covered by a cape, consisting of a single piece of shell-like material. This region is the *cephalothorax* (from Greek = head-thorax). The posterior[1] region is the *abdomen*.

1. Which region is composed of a number of similar segments?
2. Which region has the legs, antennæ (feelers), and eyes attached to it?

B. *Adaptations for walking*.

Place a crayfish in the center of a pan with enough water to cover the animal. If the crayfish does not walk, touch it with the pincers.

1. How many pairs of legs are used in walking?
2. In what directions (forward, backward, or sideways) are you able to get the crayfish to walk?
3. State whether or not the "large claws" are used in walking.
4. Are the walking legs composed of one piece or of several movable parts? Of what advantage is this to the animal?
5. (Optional.) Make a sketch (×2) of one of the legs to show its structure.

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[1] The meaning of each of these terms is explained in **6**.

C. Adaptations for swimming.

Place an active crayfish in a pan nearly filled with water. Use the following means to get it to swim: make a sudden movement toward it with the forceps or pencil; if this does not succeed, take hold of the animal near the anterior end where you can press the large pincers against the body. Do this quickly and release the animal. This action may cause the crayfish to swim in order to escape. If you cannot get this crayfish to swim, try another.

1. In what direction does the crayfish swim?
2. State whether or not the legs are used in swimming.
3. Watch the segments of the abdomen and the large appendages at the posterior end to determine their action in swimming.
    - *a.* Describe the direction of the movements of these parts.
    - *b.* Are these movements made slowly or quickly?
4. In what direction will the doubling under of the abdomen tend to send the animal?
5. In what direction will the straightening out of the abdomen tend to send the animal?
6. In what direction, therefore, must the crayfish strike the harder and quicker in order to swim backwards?
7. What difference is there in the shape of the ventral surface and the dorsal surface of the abdomen?
8. Which surface of the abdomen will enable the crayfish to get the better hold upon the water?

9. (Optional.) Straighten out and double up the segments of the abdomen, noting how the segments are connected. Describe now all the adaptations of the abdomen and its appendages for swimming?
10. (Optional.) The first segment of the abdomen (next to the cephalothorax) fits under the cape; the last is unlike the others in shape, being quite flat. Straighten

out and double up the parts of the abdomen; of how many segments is it composed?

11. (Optional.) The large appendages (*large swimmerets*) and the last segment of the abdomen taken together are called the *tail fin*. Make a sketch (× 2) of the abdomen and the large swimmerets. Label: first segment, last segment, large swimmerets, tail fin.

D. *Adaptations for breathing.*

To the Teacher. — Prepare some preserved crayfishes in the following manner: Insert the point of the scissors beneath the posterior margin of the cape that covers the cephalothorax and halfway between the middle line of the dorsal surface and the lower margin of the cape; cut forward to the front end of the cape and remove the piece of shell.

1. Immerse in water a crayfish prepared as directed above. Examine and describe the structures that you find above the legs on the side where the cape has been partially removed. These structures are the special breathing organs of the crayfish. They are known as *gills*.
2. Push the gills to one side and find the soft body wall. Higher up find the line of attachment between the shell and the body wall. You will see that the gills are not inside the body, but in a space between the body of the animal and its shell. This space is called the gill chamber.
   - *a.* In what region of the crayfish are the gill chambers found?
   - *b.* What forms the outer wall of each gill chamber? What forms the inner wall?
   - *c.* Lift up the cape on the opposite side of the animal; state where it is free from the body wall.
3. Examine the gills on a leg that has been removed from the thorax and floated on water and note

that it is largely composed of numerous slender divisions, called the *gill filaments.*

Make a sketch of the leg (× 2) with the gills attached and label gill filaments.

4. The gills are furnished with numerous minute thin-walled blood vessels and the blood in them is separated from the water only by a thin membrane. The blood flows into the gills from all parts of the body by one set of blood vessels and leaves the gills by another. Bearing in mind that breathing is essentially the same in animals as in plants (**P. B., 82**), —
   a. What gas will the blood bring from the body to be given off in the gills in the process of breathing?
   b. What gas is taken up by the blood in the gills to be carried around the body?
   c. How are the gill filaments (as stated above) fitted by structure to permit this interchange of gases?
   d. How are the delicate gill filaments protected from injury?
5. If the same water remained on the gills for some time, what changes in the relative amounts of oxygen and carbon dioxid in the water would occur? Why, then, is it necessary that a current of water should pass over the gills?
6. *Do currents of water pass through the gill chamber?* — Demonstration.

   Inject some harmless coloring matter, such as powdered carmine in water, into the posterior end of the gill chamber. Place the crayfish again in water.
   a. State what was done in this experiment.
   b. Give your observations and conclusion.
   c. What will the incoming current of water bring to the gill filaments?
   d. What will the current of water carry away from the gill filaments?

7. *How the crayfish causes a current of water to pass through the gill chambers.*

   To the Teacher. — Prepare several living crayfish so that the action of the gill bailer may be seen. To do this carefully cut off a small part of the anterior portion of the shell just over the gill scoop.

   Watch the movements of the small blade-like body in the front of the gill chamber. This body is the *gill bailer,* or *gill scoop.*

   a. Describe the movements of the gill scoop, or gill bailer.
   b. When it moves upward and forward, what effect will the gill bailer have on the water in front of it and in the gill chamber?
   c. Where can water enter the gill chamber? (See *D*, 2, *c*.)

8. (Optional.) The gill bailer is a part of one of the crayfish's mouth parts, known as the *second maxilla.* Examine a second maxilla that has been removed from the head thorax of a preserved crayfish. Place it in a watch glass half filled with water and make out the following parts: —

   a. A part shaped something like a bird's wing, composed of several pieces.
   b. The gill bailer that you have already seen.
   c. The part where the second maxilla was torn from the body, clearly shown by the shreds of muscle.

   When you have made out these parts, make a sketch of the second maxilla (× 4), and label: winglike part, gill bailer, shreds of muscle.

9. How does the shape of the gill bailer fit it for the work it does?

E. (Optional.) *Adaptations for food getting.*

1. Place an earthworm, a piece of beef, or a piece of clam near a crayfish, and describe the way in which he gets the food to his mouth.

2. Of what use may the mouth parts (easily seen in a living crayfish) be in getting food into the mouth?
3. Push the outer mouth parts of a living crayfish to one side with the forceps and find a pair of hard jaws, *mandibles*. Pry them open a little.
   a. Do they work from side to side or up and down?
   b. Describe the cutting edges of the mandibles.
   c. Of what use would these jaws be in preparing food for swallowing?

F. (Optional.) *Adaptations for protection.*

1. Describe the outer covering of the animal? Of what use is this to the animal?
2. Locate the softer parts of the crayfish's armor? How are these protected by their position?
3. Gently touch the eye of a living crayfish.
   a. Describe the movements of the eye. How might these movements be advantageous to the animal?
   b. Of what advantage may it be to the crayfish to have its eyes on stalks instead of on the surface of the head?
   c. Make a sketch (× 4) of one of the eyes on its stalk. Label: fleshy stalk, eye.
4. Of what use may the large pincers be in addition to helping in securing food? Sketch (× 1) one of the large pincers complete.

G. (Optional.) *Additional drawings.*

1. Make out the parts of one of the large antennæ. Notice the broad finlike part at the base of the antenna, then two segments, and a long lash that arises from the second segment. Sketch (×2) a large antenna. Label.
2. Make a sketch (× 1) of dorsal view of the crayfish. Label the regions, and all the appendages.

113. Habits of crayfishes. — Crayfish are found commonly throughout the United States in rivers and their tributaries where limestone is found, since lime is needed in making their hard outer covering. During the day they hide under stones, in the crevices of rocks, in the mud, and sometimes in specially constructed burrows along the banks. Since the animal backs into these hiding places, its big claws are ready for business if an enemy attacks it.

Then, too, the colors of crayfishes aid somewhat in protecting them since these colors are usually similar to the color of the bottoms of the streams in which they live. Lastly, the wide range of vision, which the stalked eyes afford must serve to warn the animal of the approach of danger. Nevertheless they do not always escape since crayfish are often captured by certain birds and fishes. In fact, crayfishes are often used by man as a bait for catching fishes.

114. Food, food getting, and digestion. — At night crayfishes crawl about in search of food, concerning which they are not at all fastidious, since dead fish and other dead animals seem to be fully as acceptable as when alive. In fact, they are natural scavengers. Crayfish seize their food with their large claws and with the aid of the small pincers on the front walking legs and with the mouth parts, especially the mandibles, reduce the food to pieces small enough to be eaten. We have seen in plants (**P. B., 63, 70, 71**) that digestion many take place in any living cell where food is stored or manufactured. Hence, plants have no special part devoted to digestion. In crayfishes, however, it is quite different, since a part of the body, known as a *digestive system,* is devoted to preparing the food for absorption and use. This digestive system consists of a food tube known as the *alimentary canal* and certain masses of cells known as *digestive glands.*

After the food is digested, it can pass into the blood by osmosis and be carried to the cells [1] of the body. When the digested food reaches the cells, it may be used by the protoplasm either in making more living matter or, as we shall now see, for the release of energy.

115. Respiration and the liberation of energy. — In our laboratory study we watched the movements of the gill bailer and saw that it caused a current of water to enter the posterior end of the gill chamber and flow over the gills, thus bringing oxygen to the filaments (Fig. 111). The thin-walled blood vessels in the filaments absorb the oxygen, and the blood then passes on into other blood vessels, which carry it back to the heart, whence it is forced all over the body of the crayfish, and so the oxygen in the blood passes into the cells as does the food. Now what becomes of the oxygen?

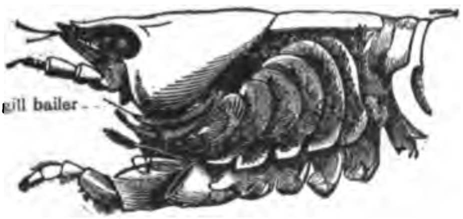

Fig. 111. — Gills of a crayfish.

As in plants (**P. B.**, **80**), the oxygen unites with elements in the foods and protoplasm of the cells and produces oxidation and liberation of energy, which gives the crayfish the power to contract its muscles and so push against the water with its abdomen and tail fin, thus propelling the animal backward, or to open its nippers and shut them and so secure food. In fact, all the work that the crayfish performs is made possible through the burning of its foods or protoplasm by the oxygen.

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[1] We have shown in plant biology (**41**) that plants consist of cells which are largely composed of living matter known as protoplasm. This is also true of animals (**126**).

Since the proteins, fats, carbohydrates, and protoplasm all contain carbon, when these are oxidized, carbon dioxid (CO_2) will be formed as one of the waste substances. All these waste substances will pass out of the cells into the blood, which finally conveys them to the filaments of the gills. Here the waste matters pass out into the water, which, as we have seen, is then forced out of the front end of the gill chamber.

116. Life history. — As in the seed-producing plants, crayfishes are reproduced by means of special cells known as egg-cells which in crayfishes are formed in the body of the female in organs known as ovaries. Before they can develop, however, these egg-cells, as in the seed plants, must be fertilized by sperm-cells, produced in spermaries of the male crayfish. After extrusion the fertilized eggs are attached by a sticky substance to small appendages, known as swimmerets, on the ventral surface of the abdomen of the female (Fig. 112). Here the fertilized egg-cell develops into a many-celled embryo, and finally a tiny crayfish is hatched. At first the young crayfishes are held to the swimmerets by threads; later they cling by means of their pincers, and after some days become independent. At intervals in both young and old crayfishes, the hard outer covering of the body is shed. This shedding of the skin is called *molting*. But for this process it would be impossible for the young to grow.

While the young crayfishes are attached to the parent they are of course protected by their position, and the female looks after them by looking out for herself. The food for the developing embryo is stored in the egg. After hatching, the young must care for themselves, and after they become independent they receive no protection at all. There is, therefore, in the case of crayfishes nothing like the parental care of higher animals.

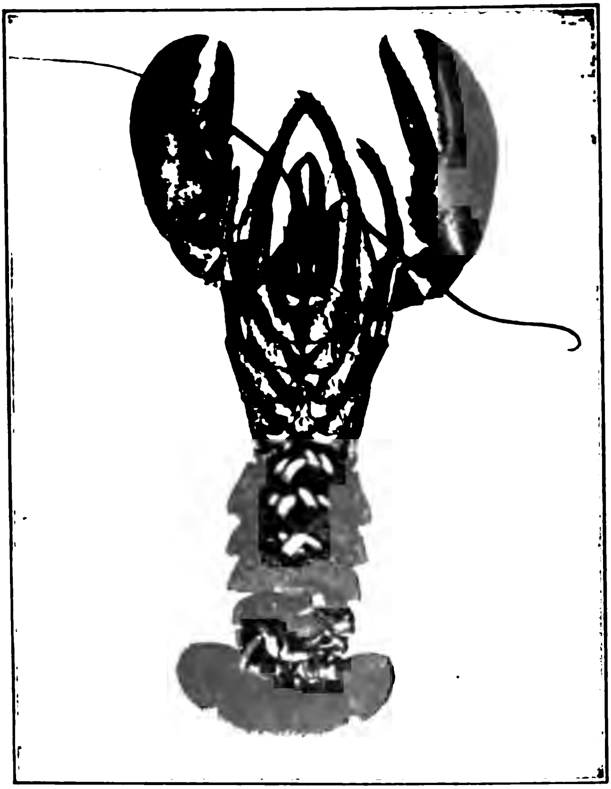


Fig. 112. — Female lobster with eggs beneath abdomen. (Herrick's "American Lobster" — United States Fish Commission.)

117. Relatives of the crayfish. — One of the relatives of the crayfish is the lobster (Fig. 112), which is a salt water animal found along the north Atlantic coast. Like the crayfish, its body consists of a cephalothorax and a clearly segmented abdomen. The lobster also has two pairs of antennæ, a pair of stalked eyes, a number of pairs of mouth parts, a pair of big claws, four pairs of walking legs, to the bases of which gills are attached, and a pair of swimmerets on each of the segments of the abdomen except the last. In general, lobsters are very much larger than crayfishes, one of the largest known specimens weighing over twenty-three pounds.

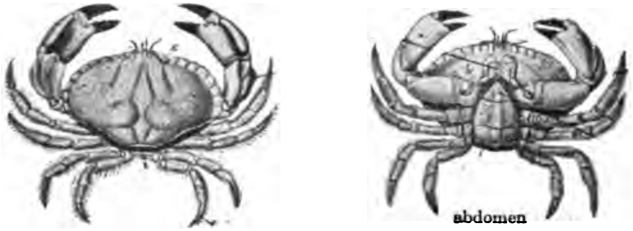


Fig. 113. — The crab.

Less like the crayfish in appearance are the crabs, yet a careful examination shows that these animals have practically all of the characteristics mentioned in the preceding paragraph. The cephalothorax of crabs, however, is usually wider than it is long (Fig. 113), and the abdomen is much reduced and is commonly folded in a groove beneath the cephalothorax. Few of the crabs are able to swim; usually they crawl sideways by the help of their four pairs of walking legs.

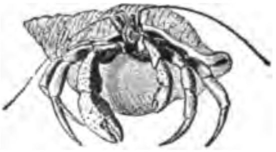


Fig. 114. — The hermit crab in an empty snail shell.

"A curious modification of habit is shown in the hermit crab (Fig. 114), which in early life backs into an empty snail shell which aids in protecting it from its enemies. The abdomen, thus covered, becomes soft and flabby. As growth proceeds the necessity arises for a larger shell, and the crab goes 'house-hunting' among the empty shells along the shore, or it may forcibly extract the snail or other hermit from the home which strikes its fancy." — Jordan and Heath, "Animal Forms."

Among the relatives of the crayfish that live in damp places on land are the pill bug and the sow bug (Fig. 115) which are often found beneath water-soaked wood. All the animals we have described in this chapter belong to the class *Crustacea*, so-called from the hard outer shell which invests them.

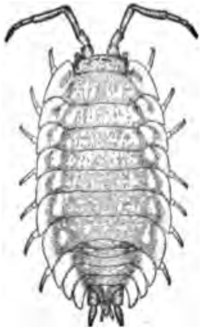


FIG. 115.—The sow bug.

118. Economic importance of the Crustacea.—Crayfishes in Europe, particularly in France, are highly esteemed as food, and special efforts are made to increase their number. In this country, however, they have, as yet, been used but little as food. Their principal use is for bait in catching certain kinds of fish.

The lobster is to us what the crayfish is to Europeans. While they are not abundant enough to be considered a very important source of food, still the fishermen in 1901 received $1,400,000 for the lobsters caught. They are considered rather as a delicacy, since they are too expensive for general use, principally on account of their scarcity. For a number of years the United States government has been making efforts to increase the number of lobsters by artificial propagation. Some states have passed laws forbidding the catching of immature lobsters and lobsters with eggs attached.

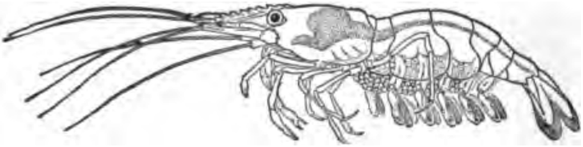


FIG. 116.—The shrimp.

Other crustacea that are used for food are prawns, shrimps (Fig. 116), and certain kinds of crabs. Nearly all the crustacea eat dead animal food; consequently they are useful in keeping the water free from dead material.

CHAPTER VI

PARAMECIUM AND ITS RELATIVES

119. Study of the paramecium. — Laboratory study.

Note to Teacher. — To secure paramecium material, add some chopped hay to a large jar of water several weeks before the animals are needed. The paramecia develop more rapidly and are of larger size if the water is secured from a stagnant pool. The hay infusion furnishes food for bacteria upon which the single-celled animals feed. To obtain the paramecia, transfer to a glass slide with a pipette a drop from near the surface of the water.

A. General appearance of paramecium.

1. Place a drop of water containing many paramecia or other similar forms on a glass slide (with concave depression if possible). Examine with a magnifier.

   Describe the appearance of the tiny bodies that you see moving about.
2. Now examine the drop of water with the low power of the compound microscope. Do not allow the water to evaporate entirely, but keep adding a little from time to time.
   - *a.* Do the paramecia swim slowly or rapidly?
   - *b.* Is the more pointed end of the animal usually foremost in swimming or the rounded end?

B. Structure of paramecium.

Secure a stained and mounted specimen of a paramecium, or add a drop of iodine solution to the water containing the living animals, and place a cover glass on top. Examine first with the low power of the microscope and then with the high power. Make a sketch two or three inches long to show the following: —

1. The general shape of one of the paramecia.
2. A fringe of slender hairlike projections around the outer surface. They are called *cilia* (singular *cilium*, from Latin, meaning a hair). The cilia are projections of the protoplasm of the cell. They project from the upper and lower surface also, but they cannot be seen readily.
3. A more deeply stained portion of the protoplasm near the center, the *nucleus* (Fig. 118). The rest of the cell is the *cell body*.
4. Particles of matter, *food particles* scattered through the body of the cell.
5. Label: cilia, nucleus, food particles, cell body.

C. Food getting.

To the drop of water containing the living paramecia add a little finely powdered carmine, and on the drop place a cover glass.

1. Tell what was done.
2. Throw all the light you can on the paramecia by means of the mirror and use the larger openings in the diaphragm. What evidence have you that the paramecia are feeding on the carmine? Sometimes it is necessary to leave the paramecia for twenty-four hours before they feed.
3. Watch the paramecia swimming through the particles of carmine. What evidence have you that the cilia are in motion?
4. The paramecium has a *furrow* on one side of its body, and from the furrow a tubular passage or *gullet* leads into the protoplasm. Both the furrow and the gullet are lined with cilia.
   - *a.* If you are able to see either the furrow or the gullet, describe them.
   - *b.* In what direction must the cilia in the furrow and

the gullet strike the swifter and with the more force to bring food particles into the gullet?

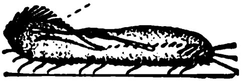
D. Locomotion. (Optional demonstration.)

Examine with a high power a paramecium that is comparatively quiet. Focus carefully and look for the cilia.

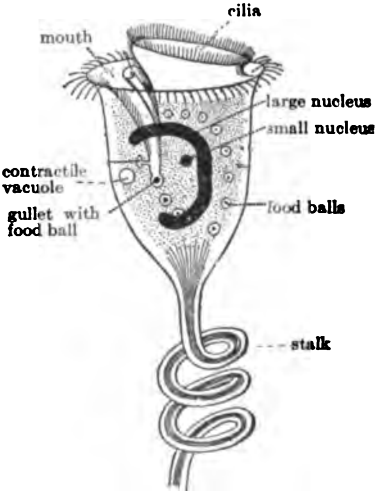
1. Describe the cilia and their movements.
2. When the paramecium strikes against the water in one direction, in what direction would its body tend to move?
3. Must the paramecium strike harder toward the blunt end or toward the pointed end when it swims with the blunt end foremost?

E. Excretion of liquid waste. (Optional demonstration.)

Look at a paramecium or vorticella with both the low and high power and search for clear circular spots. Watch to see if any of these contract. If they do, they are *contractile vacuoles*. There are two in paramecium and one



A, stylonychia



B, vorticella

FIG. 117.—Protozoa with cilia.

in vorticella (Fig. 117). The liquid waste flows from the protoplasm into these spaces, the protoplasm then pushes together and forces the waste out of the body.

1. Describe the position, appearance, and action of the contractile vacuoles.
2. State in your own words the use of the contractile vacuoles.
3. Sketch the contractile vacuoles in your drawing of the paramecium and label.

F. Reproduction of paramecium. (Optional demonstration.)

All the time while you are studying the paramecium be on the lookout for forms that are dividing. If you do not see any, examine mounted slides that show the paramecium dividing. Make a sketch three inches long of a paramecium dividing, to show how it reproduces.

120. External structure and locomotion. — In form a paramecium resembles somewhat the shape of a slipper, hence it is sometimes called the "slipper-animal" (Fig. 118). Extending from all parts of its outer surface are many tiny projections of protoplasm that look like colorless hairs; these are known as *cilia* (singular *cilium*). In locomotion

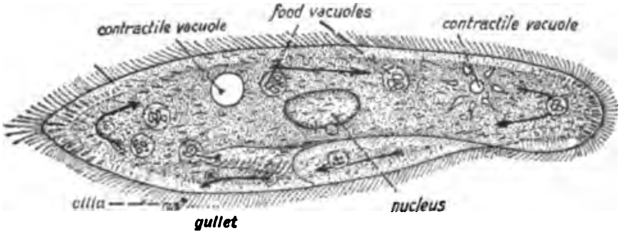


FIG. 118. — The paramecium. (Dahlgren.)

the animal usually moves with the blunt end (*i.e.* heel of the slipper) in front, the paramecium being propelled by the strong backward strokes of the cilia and a slower recovery. When it runs into an obstacle, the cilia are reversed in action and thus the animal is enabled to move with the opposite end (toe of slipper) in front. Most animals that swim (*e.g.* fishes and frogs) have broad and flat appendages which are comparatively large. In paramecium, on the other hand, the organs of locomotion (cilia), while slender, are so numerous that they perhaps accomplish the same results as the broad swimming appendages of the frogs and fishes.

121. Food, food getting, and digestion. — Paramecia feed upon one-celled plants and animals. On one side of a paramecium is a furrow or *groove*, which is lined with cilia. At the lower end of the groove is an opening, the *mouth*, which leads into a short, tubular *gullet*. The rapid motion of the cilia in the groove draws the food toward the mouth opening and other cilia lining the gullet push down the food particles. Small collections of these food particles are made at the lower end of the gullet, and these masses, *food balls*, are circulated within the cell by the streaming movement of the protoplasm. Although the paramecium is a single cell, it has certain parts specially developed for securing food, just as the higher animals have special organs for this function.

As the food balls circulate through the protoplasm, they are gradually digested, and the food materials thus liquefied are used as in plants and other animals for the production of more protoplasm or for the release of the energy needed for locomotion and for food getting. The indigestible parts of food are forced out through the side of the body.

122. Respiration and the liberation of energy. — The ˋaramecium is surrounded by water that contains oxygen and this passes into the protoplasm through the thin membrane surrounding the animal. When the oxygen combines with the chemical elements found in foods and protoplasm, oxidation is carried on, energy is released, and waste substances are formed which are given off in the process of excretion.

123. Excretion of wastes. — At either end of the animal is a clear space which is sometimes circular and at other times star-shaped. These are the *contractile vacuoles*. The wastes formed by oxidation (*e.g.* carbon dioxid and water) collect to form the vacuoles. The protoplasm presses upon the waste materials and periodically squeezes them out of the animal. When this occurs, the contractile vacuole disappears.

124. Reproduction and life history. — In the interior of a paramecium are two nuclei known as the large nucleus and the small nucleus, both of which show readily when the animal is stained with iodine or with other chemicals. When the animal reproduces, both the large and small nuclei divide in halves (Fig. 119), a new mouth and gullet are formed, and two new contractile vacuoles appear. The cell body then divides transversely, the cells separate from each other, and thus from a single individual, two new paramecia are formed. If conditions are favorable, both animals grow and may in turn reproduce at the end of twenty-four hours. "It has been estimated that one paramecium

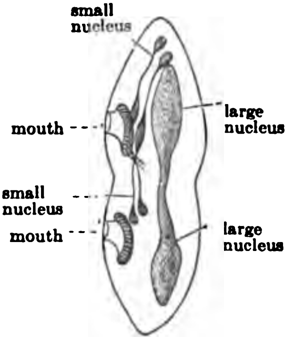


FIG. 119. — A paramecium dividing.

may be responsible for the production of 268,000,000 offspring in one month."

125. Study of amœba (plural, amœbæ or amœbas). — (Optional laboratory study.)

A. Structure of amœba.

Examine a living amœba or a stained specimen on a prepared slide. Use a low power of the compound microscope at first, and then as high a power as may be necessary. Make a sketch about three inches long to show the following: —

1. An outline to show the shape of the animal, including any projections of the protoplasm, which are called *pseudopods* (Greek *pseudo* = false + *pod* = foot; hence, the name *false foot*).
2. The main mass of the amœba, clear and jellylike in a living amœba, slightly stained in a mounted specimen, which is called the *cell body*.
3. A slightly denser part of the protoplasm in the living form or stained much darker in the preserved animal, the *nucleus*.
4. Particles of food or one-celled plants scattered through the cell body.
5. Label: false feet or pseudopods, nucleus, cell body, food particles.
6. If time allows, draw several different forms assumed by the specimen.

B. Locomotion.

In a living amœba watch with the high power of the microscope the creeping movements, and the projections of the pseudopods.

1. Are the movements slow or rapid?
2. In your own words give a description of the locomotion of the amœba.

C. Excretion of liquid waste.

Look for a clear, roundish spot in the amœba which at intervals disappears. This is the *contractile vacuole.* The liquid waste flows into this space and then the protoplasm pushes together and forces the waste out of the body.

1. Describe in your own words the appearance and action of the contractile vacuole.
2. Sketch the contractile vacuole in your drawing of the amœba and label.

126. A comparison of paramecium and amœba. — Both amœba and paramecium are animals so small that they can barely be seen with the naked eye. Both live in water, both are one-celled animals, and both carry on the same functions, but in a somewhat different manner. While the paramecium maintains a more or less fixed form, the amœba is capable of assuming almost any shape (Fig. 120). This it does by causing portions of its substance to flow out in many directions. These projections are known as *pseudopods* which mean *false feet.* By pushing out these pseudopods in front and pulling up its protoplasm from behind, the amœba slowly flows from one part of the slide to another.

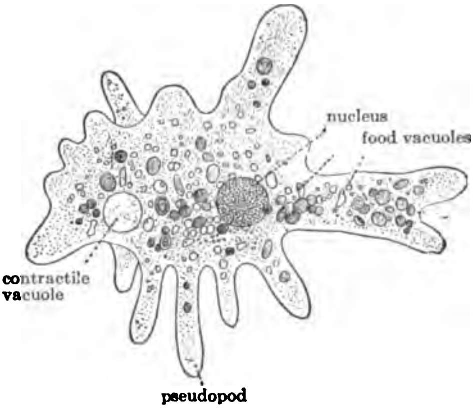


Fig. 120. — The amœba.

Unlike the paramecium an amœba has no definite part of the body through which it takes in food. When the animal is feeding, it slowly flows about the one-celled plant or animal and finally ingulfs it. The processes of digestion, assimilation, respiration, excretion, and reproduction (Fig. 121) are much the same in amœba as in paramecium. Both these animals belong to a group of animals known as the *Protozoa* (Greek *protos* = first or simplest + *zoön* = animal).

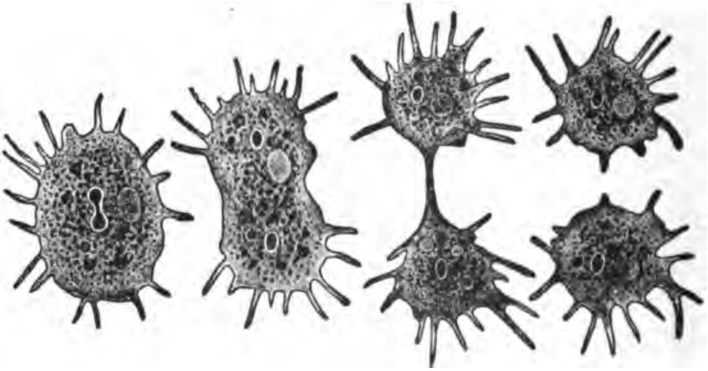


FIG. 121. — An amœba dividing.

127. To show that the higher animals are composed of many cells. — Laboratory study.

Frogs are continually shedding parts of their epidermis, and pieces of this thin membrane are likely to be seen clinging to a frog in an aquarium or floating in the water. Secure a piece of this membrane, spread it on a slide, add a drop of water and a cover glass, and examine with the low power of the microscope.

1. Describe the form and color of each cell.
2. In each cell notice a body, usually near the center and slightly more dense than the rest of the cell. This is the *cell nucleus*. (If the nucleus does not show clearly, add a drop of iodine to the membrane.) The rest of the cell is the *cell body*.
   a. Name, now, two parts of a cell of the frog's epidermis.

b. State the form and position of the cell nucleus.

3. Make a drawing of three of the cells described above, each cell to be represented about an inch in diameter. Label cell body and cell nucleus.

4. (Optional.) Demonstrate by the use of prepared slides, pictures, or charts that the blood, intestine, and other organs of the body of a frog or other higher animal are composed of cells. Make a drawing of a single cell in each case.

128. A comparison of Protozoa and the higher animals. — Our study thus far has shown that all animals, including the Protozoa, perform the necessary functions of locomotion, food getting, assimilation, respiration, and reproduction. The adaptations for performing these functions, however, are very diverse.

All animals except the Protozoa consist of many cells and the various functions of the higher animals are performed by groups of cells known as *organs*. For example, certain combinations of cells carry on locomotion, others digestion, while still others are set apart for breathing. All these functions are performed in a Protozoan by a single cell.

129. Economic importance of Protozoa. — Most of the Protozoa serve as food for other animals that live in the water and these in turn are fed upon by fish, which are eaten by man. Thus the one-celled plants and animals are found to be an important food-basis for human beings.

Some of the Protozoa that live in the sea secrete tiny shells (Fig. 122), and when the animals die the shells drop to the bottom. As a result of heat, pressure, and other causes, this bottom ooze is gradually solidified to form chalky rocks, and in the upheavals that have taken place in ages past these rocks have been forced above sea level. The chalk cliffs of Dover, England, were doubtless formed in this way.

While most of the Protozoa are harmless, there are a few forms that have become parasitic in human beings. We have already discussed the single-celled animal that causes malaria and that is carried from one individual to another by the Anopheles mosquito (**39**). This parasite resembles an amœba in form. Another form of Protozoan causes the terrible disease known as the sleeping sickness of tropical Africa. Many biologists believe that yellow fever (**41**) is caused by a protozoan that is transmitted by the Stegomyia mosquito.

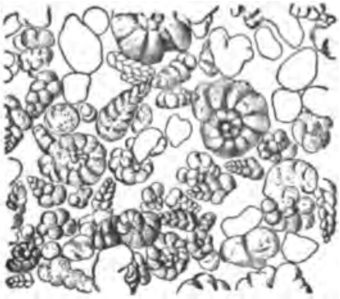


Fig. 122. — The shells of one-celled animals as they are found in chalk. (Scott, Geological Survey of Iowa.)

CHAPTER VII

ADDITIONAL ANIMAL STUDIES

A. *Porifera* (*sponges*)

130. Sponges. — The sponges are animals more complex in structure than the Protozoa, for they are composed of many cells; nevertheless, they are comparatively simple in structure since they have no digestive, circulatory, respiratory, or nervous system, and therefore each cell has to carry on practically all the necessary nutritive functions.

Sponges differ largely in the kind of skeletons that they possess. In the common bath sponge (Fig. 123) this is composed of a tough, horny material. When sponges are ready for market, only the horny skeleton remains, the living cells having been killed and removed. The sponge skeleton shows a large number of pores in the outer surface, and for this reason the name *Porifera* (Latin = pore-bearing) is given to this group of animals. The pores lead into canals that run through the body, finally connecting with one or more larger central cavities that lead outward, usually at the top. In certain parts of these canals there are cells with cilia; their action causes water to rush into the canals through the pores, bringing food and oxygen to all the cells of which the sponge is

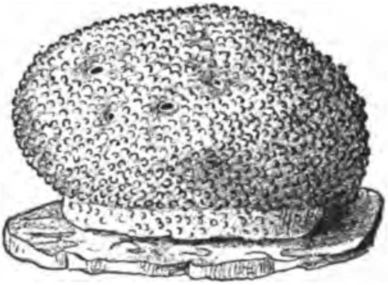


FIG. 123. — Bath sponge.

composed. The wastes are forced out through the larger canals referred to above. Like the bath sponge, all other Porifera are stationary in their mature form.

B. Cœlenterata

131. Hydra. — A study of a fresh water cœlenterate known as hydra will give one a fair idea of the structure and adaptations of this group of animals. Hydra is a small animal found in fresh water attached to water plants, and sometimes to surfaces of stones or other objects on the bottom. At the upper end of the tiny cylindrical *column* are threadlike bodies known as *tentacles* (Fig. 125, *1*). If the animal is touched with a needle or pencil, it contracts its body and tentacles so much that it can scarcely be seen. But in a short time it expands again.

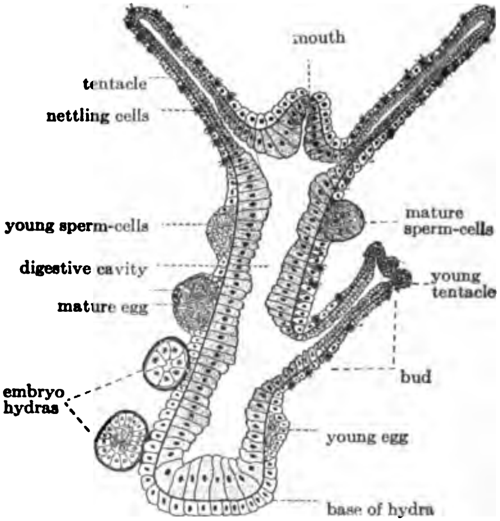


FIG. 124. — Longitudinal section of a hydra. (Hegner.)

If the hydra happens to be hungry and some small form of animal comes in contact with the waving tentacles, the hydra ejects microscopic threads from certain cells (*nettling cells*) in the tentacles. The animal thus attacked is benumbed, and the hydra then uses the tentacles to push its prey into a mouth opening in the center of the circular row of tentacles. The food is drawn into the inside of the column, which is simply a hollow tube (Fig. 124). Here certain cells secrete digestive ferments which dissolve the foods that the animal has eaten, and the indigestible matter is ejected from the mouth. The digested food is then absorbed by the cells lining the cavity. Since the animal is bathed outside and inside by water containing oxygen, the cells are able to absorb oxygen from the water and to give off carbon dioxid to the water. Hence no breathing organs are needed.

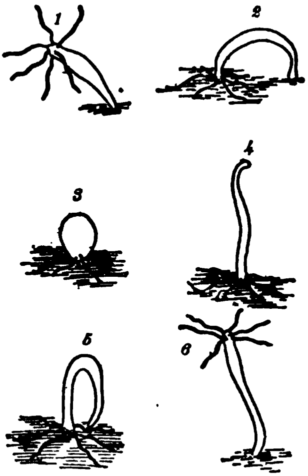


FIG. 125. — The movements made by hydra in locomotion. (Jennings.)

It is evident that the tentacles with the nettling cells also serve to protect the hydra from too great familiarity on the part of visitors that might otherwise use it for food. When the hydra moves from one place to another, it bends over until the ends of the tentacles touch the surface on which it rests. The tentacles then adhere to this surface, the bottom of the column lets go, and the animal turns a somersault (Fig. 125) and lands on the lower part of the column; the process may then be again repeated.

Like the higher animals the hydra reproduces by means of eggs and sperms. But it also has another interesting way of producing new individuals. On the surface of the column one frequently sees little bunches. These are called *buds* (Fig. 124). They keep on growing outward till at last little tentacles and a mouth opening are formed at the tip of each. It is now evident that we are looking at a very tiny hydra. Finally the new individuals separate from the column and begin an independent life. This method of reproduction is known as *budding*.

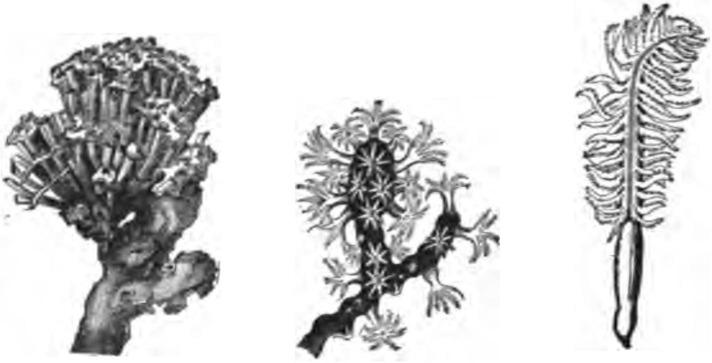

A, organ-pipe coral *B*, precious coral *C*, sea-feather

FIG. 126. — Different forms of coral.

132. Suggestions for the study of hydra. — Laboratory study. Pupils should be supplied with living hydra if possible. The column and tentacles should be observed by the aid of a magnifier, described and drawn. The animal should be touched and the action of the column and tentacles noted and described. If the hydra moves from place to place, the method of locomotion should also be described.

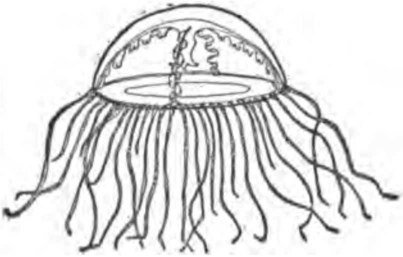


FIG. 127. — Jellyfish. (Hargitt.)

133. Relatives of hydra. — Among the relatives of hydra are the corals (Fig. 126), sea-anemones, and jellyfish (Fig. 127). One form of coral, the red coral, is of considerable economic importance. In all the corals the column secretes a mineral substance within which the animal can withdraw when danger threatens. In the case of the red coral this material is horny. It is used for decoration, and some communities on the Mediterranean are devoted largely to the gathering of this coral, and to making it into various forms of jewelry.

C. Annelida

134. Earthworm. — The most common representative of the annelida is the earthworm (Fig. 128). The general form of this animal is long and cylindrical. If one places an earthworm on the ground, it will start to crawl away or bore into the soil. Observe that the end that is foremost is tapering. This is the *anterior end.* The opposite or *posterior end* is broader and considerably flattened. The part of the body on which the worm crawls is the ventral surface, which is somewhat flattened, while the dorsal surface is rounded. The whole body is composed of rings or *segments.* About one third of the distance from the anterior end of the worm several of the segments are usually somewhat enlarged and form the *girdle.*

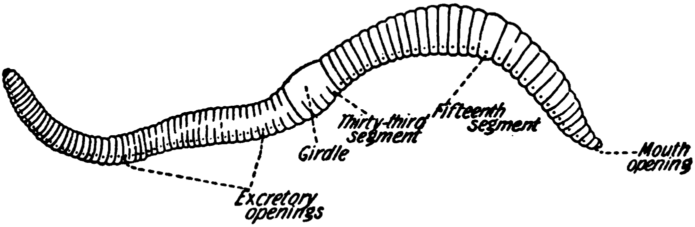


FIG. 128. — The earthworm. (Sedgwick and Wilson.)

At the anterior end toward the ventral surface, there is a small opening. This is the mouth, and through it the earthworm sucks in its food which consists not only of dirt, but of leaves of various kinds. Overhanging the mouth is a tiny projection, the *lip.* The animal has no special breathing organs. The skin, however, is permeated with capillaries, and thus serves as a breathing organ.

Locomotion is brought about by alternately lengthening and then shortening one portion of the body after another. On the ventral region of the body are rows of bristles which aid in locomotion. The bristles project backward when the worm is moving forward, and so keep the animal from slipping backward when it lengthens itself. The bristles also serve to hold the animal in its burrow.

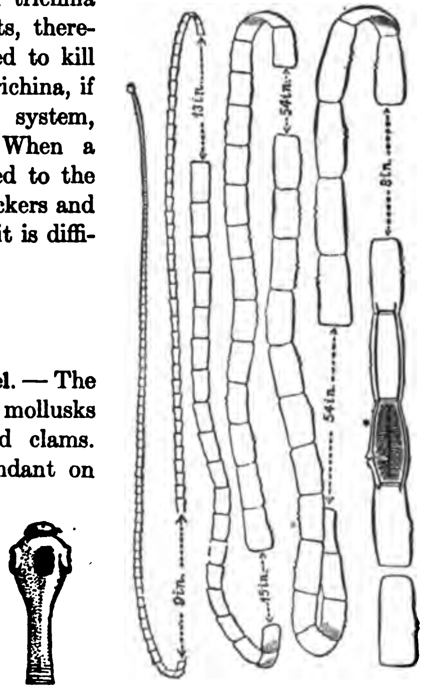
Earthworms are of considerable value in the soil. They burrow through the earth by swallowing the dirt which is mixed with vegetable matter; both are then acted upon by digestive juices in the alimentary canal. The refuse of the food, which is not available for use in the body, is ejected from the posterior end of the intestine. The little piles of dirt that are sometimes so common on a lawn are the " castings " of earthworms. It has been found that soil worked over by these animals is in better condition for the growth of plants. Then, too, the deeper soil that has not been used by plants is brought to the surface and mingled with the dirt recently used. Darwin[1] estimated that in England earthworms annually bring to the top of the ground eighteen tons of soil per acre.

135. Suggestions for the study of the earthworm. — Laboratory study.

This study should be made upon living worms. The pupil should first note and describe the general shape and segmentation of the animal, the differences between the anterior and posterior ends, the dorsal and ventral surfaces, and the characteristic appearance of the girdle. An earthworm should be placed on a moist surface such as soil or wet paper, and the locomotion of the animal observed and described. A large specimen should be pulled, anterior end first, between the fingers, and the action of the bristles noted and their situation and appearance studied with the help of a magnifier. Touch the earthworm on various parts of the body, and determine, if possible, which portions are the most sensitive. Look on the dorsal and ventral surfaces for blood vessels, and watch the pulsations of the blood in these vessels; describe the location of these blood vessels and state the direction in which blood flows in each of them.

[1] Darwin's "Vegetable Mold and Earthworms."

136. Relatives of the earthworm. — Two forms of animals that formerly were classed with the earthworm under the head of "worms" are the tapeworm (Fig. 129) and trichina. The tape worm is sometimes present in beef and trichina (Fig. 130) in pork. Meats, therefore, should be well cooked to kill all such parasites. The trichina, if it gets into the human system, causes great suffering. When a tapeworm becomes attached to the human intestine by the suckers and hooks on its anterior end, it is difficult to dislodge.



A, head of tapeworm

B, tapeworm, about 15 feet long, omitted portions being indicated

FIG. 129. — The tapeworm. (Shipley and MacBride.)

D. Mollusca

137. Fresh water mussel. — The fresh water mussels are mollusks that are sometimes called clams. They are often quite abundant on the bottom of creeks, rivers, ponds, or lakes. Usually they are partly covered with sand or mud, sometimes even more than is shown in Figure 131. It will be seen at once that the mussel is inclosed by a shell. This consists of two parts called *valves;* hence these animals, as well as salt water mussels, clams, and oysters are called *bivalves* (Latin *bis* = two + valve). The two valves are held together along one margin by a tough material that serves as a hinge. On each valve near the hinge, a prominence, known as the *beak* or *umbo,* may be readily seen. Around the umbo, in ever widening concentric rings, are the lines of growth of the animal, which indicate younger stages in its development.

Let us now pull up a mussel and lay it on a sandy bottom. In a few moments the shell will open somewhat and from one end will project a pinkish body, which may finally extend some distance. This organ is the *foot*. If we watch long enough, we may see the mussel use the foot to push itself over the surface of the sand or it may burrow into the sand, and finally come to occupy a position like that in which we found it.

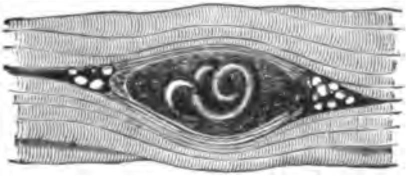


Fig. 130. — Trichina in Muscle. (Leuckart.)

Now if one is patient, and the animal feels at home, it will be possible to see the method of eating and breathing. At the end opposite the foot there may slightly project from the shell a fringed and somewhat tubular-shaped structure. Let us place a little finely powdered carmine in the water above the opening. As the carmine slowly sinks and comes opposite the tube, the particles will suddenly be drawn into the tube. This shows that water is being sucked into the tube, and it brings with it oxygen and any food that may be near, such as microscopic plants and animals.

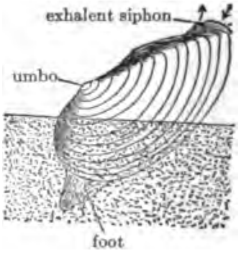


Fig. 131. — Mussel burrowing in sand.

To learn any more about the feeding and breathing of the mussel it will be necessary to open the shell. Let us take another mollusk and pry open the valves. We shall soon find that this is not easy to do. The reason will be evident after studying Figure 132.

The valves are held together by strong muscles. So we pry the valves open a little with a heavy knife and then slip another sharp knife in close to the valve, where we meet an obstruction toward one end. When we have cut this, the valve opens at that end. After cutting the muscle at the other end, we can readily separate the valves. All over the surface of the animal, except where the two muscles were attached to the shell, is a thin covering called the *mantle.* By raising the body of the mussel from the valve it will be evident that there is a similar structure on the other side.

Now, if we fold back the mantle, it will be possible to follow the course of the food and water. The first thing that strikes our attention is the contracted foot, and above this is a soft mass called the *abdomen.* In the abdomen are found the *digestive organs.* On each side of the abdomen are two broad, thin flaps, the *gills,* by which the animal breathes. Between the foot and the end that was buried in the sand are found, on either side of the body, two small flaps or *palps,* and between them lies the *mouth opening.* To this mouth the food that has been swept into the tube is brought by the waving of thousands of cilia that are found on the surface cells of the gills and palps.

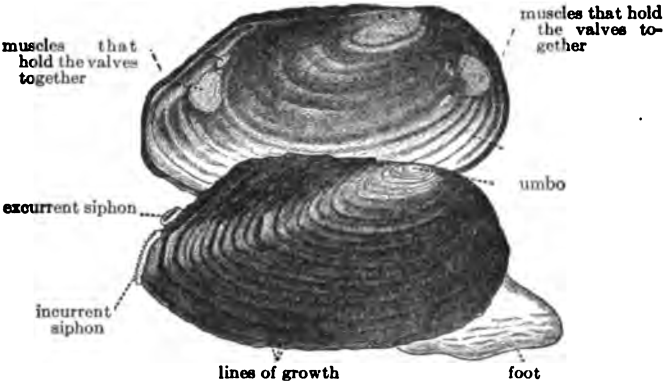

muscles that hold the valves together
muscles that hold the valves together
umbo
excurrent siphon
incurrent siphon
lines of growth
foot

FIG. 132. — Fresh water mussel with foot extended.

Let us now return to the study of the mussel partly covered by the sand. The hinge is on the dorsal region of the body, the free edges of the valves on the ventral, while the mouth and foot are at the anterior end. Hence, the animal in its natural position "stands on its head," or at least where its head ought to be. From the posterior end projects the tubular structure to which reference has been made.

Let us again drop some powdered carmine closer to the animal, and watch the particles when they reach a point just above the tube where we saw the particles enter. We shall now see the carmine carried away from the animal instead of into it. A closer examination reveals the fact that the tubular structure has a second opening above the first. Both of these tubes are called *siphons*, the lower being the *incurrent siphon*, and the upper the *excurrent siphon*. The stream of water forced out of the excurrent siphon carries with it the carbon dioxid and other wastes of the body.

138. Suggestions for study of the mussel. — It is desirable to have students see the mussel in its natural home. They should tell where they found the animals and the positions in which they were seen. It would then be well for the pupil to study in the laboratory the shell, making out the points of structure described above. A drawing of a side view of the mussel should be made and labeled as follows: valve, umbo, hinge, lines of growth, anterior region, posterior region, dorsal edge, ventral edge. It is also desirable that a drawing of the animal in the sand or mud be made and the incurrent and excurrent siphon openings be labeled.

The pupil might well follow the account as given above, verifying the statements and experiments, and making drawings of the mussel with the shell open and all the animal lying in one valve. Label: mantle, muscles that close shell, incurrent siphon, excurrent siphon. Also a drawing should be made of the mussel with the mantle removed. Label: foot, abdomen, palps, mouth, gills. Write an account of how the mussel moves or burrows, how it feeds and breathes.

139. Relatives of the mussel. — Some of the relatives of the mussel are the clams, oysters, salt water mussels, snails (Fig. 133), and slugs. While the fresh water mussels are not much used for food, they are important economically on account of the pearly matter that is found on the inside of their shells. This is used in making buttons and other articles. In fact, there is a considerable industry in this line along the Mississippi River.

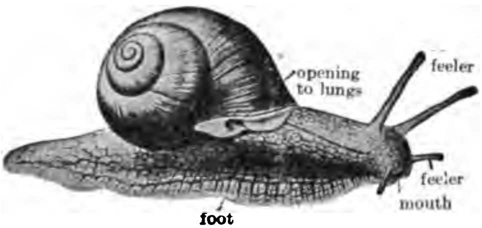


FIG. 133. — The snail.

Oysters are important as an article of food. The oyster fishermen receive annually from twenty to thirty millions of dollars from these mollusks collected from the oyster beds along the Atlantic Coast. A certain kind of mollusk, known as the *pearl* oyster, secretes within its shell the pearls of commerce. These are formed of a material similar to that found on the inner layers of the fresh water mussel.

E. Reptiles

140. The turtle. — The body of a turtle may be divided into four regions; namely, head, neck, trunk, and tail. The larger part of a turtle, the trunk, is covered by a shell, and to this shell the bony skeleton is firmly united. The two pairs of legs, however, are freely movable, but can be drawn within the shell for protection. The toes of the feet are armed with sharp, curved nails, and the legs are covered with scales. The legs are used for walking and also for swimming. In some turtles the legs become broad and flat and are of but little use except for swimming.

The head, neck, and tail can also be drawn into the shell. Scales cover the neck and part of the head. The jaws of the turtle, often called the beak, possess no teeth. The eyes, protected by the eyelids, the nostrils, and the ear openings, are readily seen.

Turtles reproduce by means of eggs, which are comparatively large. Turtle eggs are often used for food. These animals breathe throughout their entire life by means of lungs.

141. Suggestions for the study of the turtle. — Turtles are easily kept at home or in the laboratory. The pupil should verify the statements given above concerning the turtle, and should then write an account of his observations in his notebook; or a well-labeled drawing will cover most of the ground. The pupil should also observe and describe in his notebook the methods by which the turtle feeds, crawls, swims, and protects its head, legs, and tail.

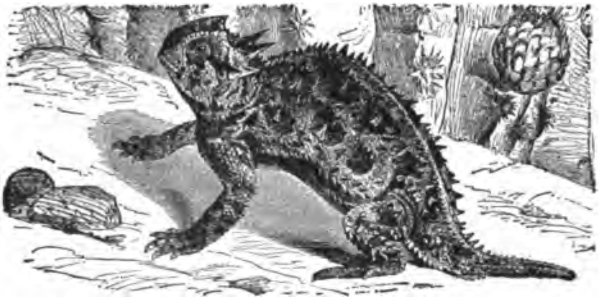


FIG. 134. — Lizard of the Southwest (commonly known as the "horned toad").

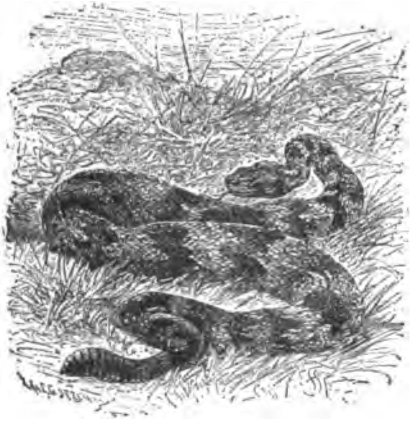


FIG. 135. — The rattlesnake.

142. Relatives of the turtle. — Animals related to the turtle are the lizards (Fig. 134), alligators and crocodiles, and snakes (Fig. 135), all of these animals being known as reptiles. None of the reptiles, other than the turtles, possess a shell, but all are covered with scales, and have toes armed with claws, except the snakes which have no appendages. Unlike the turtles the jaws of all other reptiles contain sharp teeth, used in holding their prey, and in the rattlesnake and copperhead some of these teeth are provided with poison glands. None of the other reptiles in the northern part of the United States are in any way dangerous to man. Indeed, many snakes destroy large numbers of rats and mice, while lizards catch large numbers of insects. The hide of the alligator is of considerable value for leather. All reptiles breathe throughout their life by lungs, and most of them reproduce by eggs, which are hatched by the warmth of the sun.

F. Mammals

143. Characteristics of mammals. — In this class of vertebrates are included domesticated animals such as the cow, sheep, horse, camel, dog, and cat. Let us consider the structure of some of these animals to see why they should be grouped together. We are familiar enough with the animals named above to know that they all have a head, neck, trunk, and tail and that these regions are covered with hair. A few mammals, *e.g.* the baboons, have no tail, and a few are nearly destitute of hair, like the whales (Fig. 136); but all of them nourish their young on milk produced in certain organs known as mammary glands; hence these animals are called *mammals.*

FIG. 136. — The sperm whale.

The organs of the head, namely the ears, eyes with eyelids, and the nostrils, are prominent in all common mammals, but vary in size and shape. The jaws have teeth set in sockets, but the number and kinds of teeth vary greatly. Rats, rabbits, and squirrels, for example, have sharp cutting teeth (*incisors*) and grinding teeth (*molars*). Others, *e.g.* dogs, cats, lions, and tigers, have sharp pointed incisors and molars and in addition long *canine* teeth for tearing their food. In horses, cows, and other herbivorous animals the grinding teeth are especially developed, while canine teeth are either wanting or are relatively small.

All these animals have four legs, but the relative size of the front and hind legs may differ greatly. In a kangaroo, for instance, the hind legs are very large, while the front pair are so small as to be practically useless. Then, too, the nails on the toes vary considerably. The fingers and toes of man are protected on a surface by nails. A horse has only one toe on each foot, and the nail for that toe is developed into a *hoof*. Cows and sheep have two toes on each foot similarly protected. On this account these mammals and others like them are called the *hoofed mammals*.

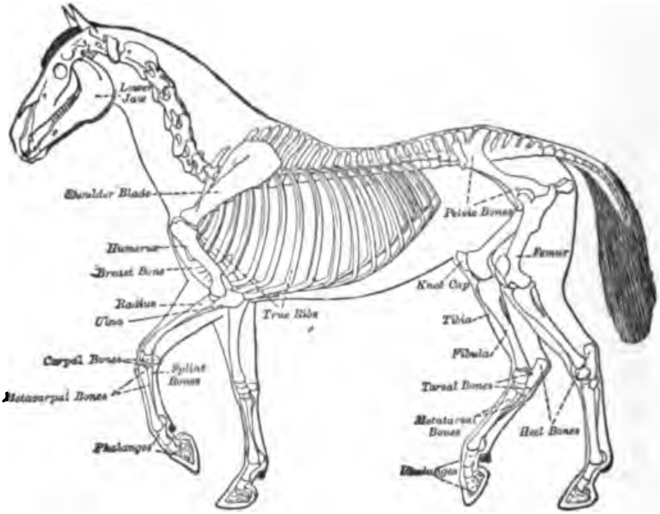


FIG. 137. — Skeleton of the horse.

An examination of the skeleton of a horse (Fig. 137) or of most mammals, shows that the skeleton consists of bones similar to those of man. Thus, for instance, there is the spinal column made up of a series of more or less similar bones, with a skull that may vary a great deal in shape from that of man, but still may consist of similar bones. The shoulder bones and hip bones can be readily distinguished. The bones of the legs are for the most part much alike, but in the foot there is frequently a wide variation, as in the case of the one-toed foot of the horse, the two-toed foot of a cow, the three toes of the tapir, the four of a hippopotamus, and the five of the dog or of man.

144. Suggestions for the study of a mammal. — Follow the general account given above and describe the corresponding structures of a horse, dog, cat, or other mammal. Thus, for instance, name the regions present, and describe the character of the covering of each region. Then describe the situation and parts of the eyes, the situation, size, and shape of the external ears, the location of the nostrils, and so on to the end of the study. Lastly, describe the methods of locomotion of the animal, and its food and feeding habits.

145. Economic importance of mammals. — The mammals include many of our most useful animals as well as those that are very dangerous. Our common beasts of burden, horses and mules in this country, the llama of South America, the elephant and camel of Asia and Africa, are all mammals. This group of animals also furnishes us with an immense amount of material valuable for food or clothing (*e.g.* the cow, deer, sheep, pig, seal). The group of carnivorous mammals contains one of man's most devoted friends and protectors, the dog. To the same order as the dog, however, belong the wolves, lions, tigers, hyenas, and wild cats; all these have canine teeth which they use with deadly effect in tearing their prey. The gnawing mammals (*e.g.* rats and mice) besides being a nuisance, do a great deal of damage. The rat also scatters diseases like cholera and bubonic plague. Some rodents, the beaver, for example, are valuable on account of their fur. The rapacity of man, however, has nearly exterminated these very interesting animals.

G. Classification of Animals

146. Vertebrates and invertebrates. — All animals may be divided into two great groups, known respectively as *vertebrates* and *invertebrates*. To the first group belong the animals that have a "backbone" or spinal column composed of a series of bones known as *vertebræ*. To this group belong fishes, frogs, turtles, birds, rabbits, and human beings, for all of them have a spinal column made up of vertebræ. Insects, earthworms, and oysters, on the other hand, have no backbone; hence, they are called invertebrates (*i.e.* animals without vertebræ).

147. Summary of the classification of the invertebrates. — While the vertebrates, on account of their size, are more familiar to most people, in reality there are a great many more kinds of invertebrates than vertebrates. For example, over 300,000 different species of insects have been described, more than all other species of animals put together. The invertebrates are divided by zoölogists into ten or more *branches* or *subkingdoms*, some of the most common of which are named in the table on pages 192 and 193.

148. Summary of the classification of the vertebrates. — The *vertebrate branch* of the animal kingdom is divided into five distinct *classes*. The striking characteristics of each of these classes will be seen by studying the table on page 194.

149. Reproduction among the vertebrates. — Among the animals belonging to the two lowest vertebrate groups, namely, the fish and amphibia, the female forms eggs within the body and deposits them in the water. Before these eggs can develop, however, they must be fertilized by sperm-cells produced by the male, and this is likewise true of all the higher animals and plants. The fertilized eggs develop into embryos by the process of cell division, and enough food is stored in the egg to supply the young animal until it can secure its own food. Much the same is true also in the case of reptiles, except that the eggs are usually laid in the sand and left to develop by the warmth of the sun. There are, however, certain exceptions to the general statements made above. Some of the sharks, for example, and certain of the snakes, instead of depositing eggs that develop into embryos in the water or on land, retain the eggs, and the young are born in a form much like that of the adult.

Very few of the animals belonging to the classes that we have been discussing (namely, the fishes, amphibia, and reptiles) ever take any care of their young. The great majority of birds, however, not only build nests in which to lay their eggs, but they also brood over their eggs until they are hatched, and then the parents feed the young until they are ready to fly.

A few of the lowest mammals, like most of the vertebrates named above, lay eggs. By all the common mammals, however, the eggs are not laid, but as was the case with certain sharks and snakes, the eggs develop into a form resembling the parent, before being born. All mammals at birth, unlike birds, are unable to eat the food that is used by their parents. Hence, a form of food that is easily digestible must be furnished. This is secreted by certain cells of the adults in the form of milk. The masses of cells that secrete milk are known as *mammary glands*, and because of the presence of these glands in all animals of this the highest group of vertebrates, this class is known as the *mammals*.

NAME OF BRANCH	EXAMPLE	GENERAL CHARACTERISTICS	METHOD OF BREATHING	METHOD OF FEEDING	METHOD OF LOCOMOTION
Protozoa (first animals)	Paramecium Amœba	This group includes all the single-celled animals	Through outer surface of cell	By means of cilia or pseudopods	By means of cilia or by the movement of all the protoplasm
Porifera (pore-bearing)	Common bath sponge	Pores all over the body — many-celled, but without digestive, circulatory, or nervous systems	By means of cilia currents of water bring oxygen to all the cells and remove wastes	By means of cilia currents of water bring food to all the cells	In the mature form, sponges are fixed
Cœlenterata (hollow digestive tract)	Corals Jellyfishes	Body cavity and digestive cavity one and the same	Cells of exterior and interior bathed by water	By means of tentacles supplied with stinging cells which bring food to mouth	Corals are fixed in mature stage Jellyfish carry on locomotion by enlarging and contracting the bell-shaped body

Annelida (body made of rings)	Earthworm	Parts of the elongated body arranged in rings. No jointed appendages	By means of soft, moist skin	By means of sucking mouth at anterior end	Earthworms carry on locomotion by elongating and contracting the segments, aided by bristles
Mollusca (soft-bodied)	Oyster Clam Snail	Soft body, usually covered by shell	By means of gills, or soft, moist skin	By means of cilia in clams that bring food into mouth; by raspingtongue in snails	Oysters are fixed in adult stage Clams and snails carry on locomotion by means of muscular " foot "
Arthropoda (jointed feet)	Insects Crustacea Spiders	Segmented body, jointed appendages	By means of air tubes in insects; gills, in crustacea.	By means of jointed mouth parts	By means of legs and wings in insects By means of abdomen and swimmerets in crayfish

CLASS	EXAMPLE	COVERING OF BODY	WARM OR COLD BLOODED[1]	APPENDAGES USED IN LOCOMOTION	ORGANS OF RESPIRATION
Fishes	Codfish	Scaly skin	Cold blooded	Fins	Gills
Amphibia	Frogs	Naked skin	Cold blooded	Two pairs append. Toes without claws	Gills in tadpole, lungs in adult
Reptiles	Turtles Lizards	Scaly skin	Cold blooded	Two pairs append. Toes with claws	Lungs throughout life
Birds	Robins Sparrows	Skin with feathers	Warm blooded	Anterior append. wings; poster. append. with claws	Lungs
Mammals	Cows Man	Skin with hair	Warm blooded	Paired append. with nails	Lungs

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[1] Cold-blooded animals are those animals in which the temperature of the blood changes with the temperature of their surroundings. Warm-blooded animals, on the other hand, maintain under normal conditions an almost constant temperature. The temperature of the human body, for example, is 98.6° F., which is usually higher than the temperature of the earth, air, and water; consequently when we touch a fish or frog, the animal feels cold.

LOUIS PASTEUR

CHEMIST AND BIOLOGIST

"He saved more lives than Napoleon took in all his wars."

See pages 168–170.

HUMAN BIOLOGY

CHAPTER I

THE GENERAL STRUCTURE OF THE HUMAN BODY

1. Regions of the body. — In man and in most other mammals one can distinguish at least three regions; namely, the head, neck, and trunk. To the trunk are attached two pairs of appendages; namely, two arms and two legs, or, as they are more often called in the descriptions of the lower animals, the four legs. If the front wall of the trunk (composed largely of skin and muscle) were removed, it would be found that this region of the human body is divided into an upper story or *chest cavity* (Fig. 1), and a lower story or *abdominal cavity*. These two cavities are separated from each other by a flexible partition called the *diaphragm*, which is composed largely of muscle more or less in the form of a dome. The chest and abdominal cavities, separated by a diaphragm, are characteristic of all mammals.

2. Organs of the body.[1] — When we study the body more closely, especially its interior, we find, in various regions, parts that carry on special kinds of work (Fig. 2). Within the chest cavity is the *heart*, which forces blood through the body. Here, also, are the *lungs*, which take in oxygen and give it to the blood, and which remove carbon dioxid, water, and other waste matters from the blood. Below the diaphragm are the *stomach* and the *intestines*, the *liver* and the

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[1] Each of the structures named in this paragraph should be demonstrated on a manikin or a chart before the textbook lesson is assigned. While studying the lesson, the pupil should find in Fig. 2 each of the organs named.

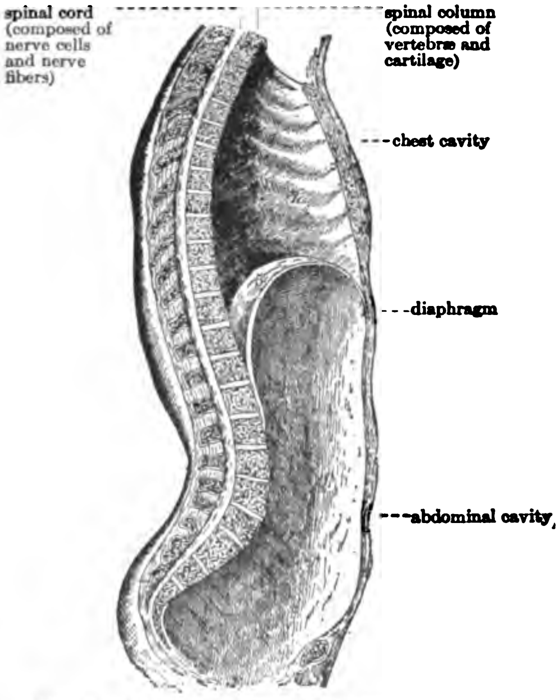
spinal cord (composed of nerve cells and nerve fibers)
spinal column (composed of vertebræ and cartilage)
chest cavity
diaphragm
abdominal cavity

FIG. 1.—Longitudinal section of trunk (side view).

pancreas, all of which help to change our food into liquid form ready to be used by the body. All these and other parts of the body are called *organs*. *An organ is a part of a living body that has some special work to do; this special work is called its function.* Our hands, for example, are organs because with them we do some special work like writing, sewing, or playing the piano.

3. Tissues of the body. — When we squeeze the arm or the hand, we feel the hard *bones* within that form the skeleton. We can raise from the bones the softer fleshy material, which is composed of muscle covered by skin. By clenching the fingers tightly we can see and feel on the inner side of the wrist the tough cords or *tendons* of *connective tissue* that

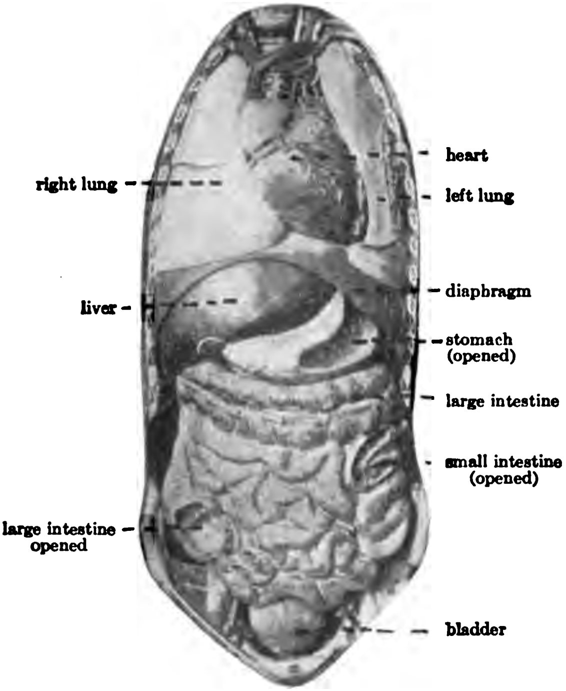

FIG. 2. — Organs of chest and abdomen (front view).

attach the muscles to the bones. If we run a clean needle point into the finger, blood flows; in this way we discover another of the materials found in our hand; namely, *blood.* This experiment also demonstrates that the human body has some structures by the help of which sensations of touch or pain are perceived. All the parts of the hand we have been enumerating are known as *tissues.* For the present *a tissue may be defined as one of the building materials of which an organ is composed.* In the hand we have found evidence of the presence of bone tissue, muscle tissue, connective tissue, blood tissue, and nerve tissue. Other kinds of tissue will be discussed in the pages that follow.

In order to go farther in our study of structure we need the aid of the compound microscope. With this instrument we discover that the tissues are by no means the simplest part of an animal.

4. Cells lining the mouth. — Laboratory study.

Materials: Cells from the human body may be readily prepared by gently scraping with the finger nail the mucous membrane lining the mouth and then rubbing the material thus obtained on a clean glass slide, adding a drop of water and a cover glass. The cells may be stained with iodine in order to show the nucleus more sharply. If time allows, prepared sections of the brain, intestines, skin, and other organs of the body may well be shown.

Examine with the low power of the compound microscope the cells prepared as described above.

1. Describe the form and color of each cell before it is stained with iodine.
2. In the cells stained with iodine notice a body, usually near the center, that is more deeply stained than the rest of the cell. This is the *cell nucleus,* and the rest of the cell is known as the *cell body.* The nucleus may be seen in the unstained cells as a denser portion.

a. Name, now, two parts of a cell from the membrane lining the mouth.

b. State the form and position of the cell nucleus.

3. Make a drawing of two of the cells described above (each cell to be represented about an inch in diameter). Label cell body and cell nucleus.

4. (Optional.) Demonstrate by the use of prepared slides, pictures, or charts that the brain, the intestine, and other organs of the body are composed of cells (Fig. 3).

5. Cells and protoplasm.[1] — Under the microscope cells at first appear to be only plane surfaces surrounded by lines (Fig. 3). In reality, however, each cell has not only length and breadth, but also thickness. Cells in animals and human beings differ from those in plants in never having cell walls of *cellulose*, and often cell walls are entirely wanting. If present, the cell wall is so transparent that it is possible to look through it and see the cell body and nucleus within.

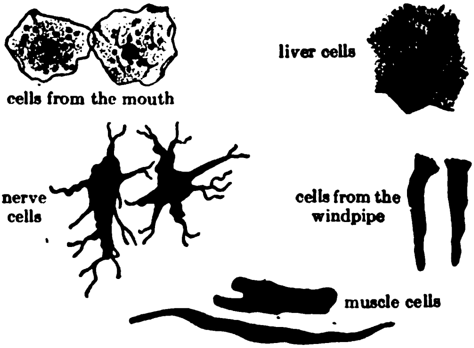

Fig. 3. — Cells from tissues of body.

The discovery of these minute bodies of which organs are composed was not made until about the middle of the last century (1838). With the rather imperfect microscopes then in use the two discoverers, Schleiden and Schwann, could see the walls only, and they did not know, as we now know, that the most important part of the cell is not the lifeless wall of cellulose, but the living substance which is found inside the cell wall, making up a large part of the cell body and cell nucleus. To this substance is given the name *protoplasm.* We know now that the living substance or protoplasm is the essential part, while the wall may be missing, so that in such a case there is no resemblance to a cell or box. Biologists now understand *a cell to be a bit of protoplasm* (*cell body*) *containing a nucleus* (which is a denser portion of the protoplasm).

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[1] Because of the importance of emphasizing cellular structure, the substance of §§ 42 and 43, "Plant Biology," are here inserted.

Protoplasm, when examined with the highest powers of the microscope, appears as a colorless, semifluid substance, in which are often seen solid particles or granules, which are probably little masses of food. The nucleus, as already stated, is commonly found near the center of the cell, and is composed of protoplasm denser than the protoplasm of the rest of the body of the cell. The appearance and composition of the protoplasm surrounding the nucleus, that is, the cell body, may be well represented by raw white of egg; but in making this comparison one should bear in mind that the white of an egg is not living substance.

6. Assimilation, growth, and cell division. — Within the protoplasm are foods in solution (such as sugar, protein, and mineral matters). These are used by cells in their growth and repair, and in the various kinds of work that they carry on. In the human body, as in plants, the food materials are gradually changed by protoplasm into living substance like itself. To this process is given the name *assimilation* (Latin, *ad* = to + *similis* = like). As a result of the process of assimilation the amount of protoplasm of course increases and the cell grows. Were this process to continue indefinitely, cells would come to be large in size. This, however, does not occur; for when a cell reaches its normal size, the nucleus divides (Fig. 4), and the halves separate from each other to form two nuclei. The cell body now divides into two parts, and cell walls are formed between the two cells. Thus are produced two cells, each having its own nucleus, and these in turn assimilate and divide. In this way the number of cells increases with the growth of the body.

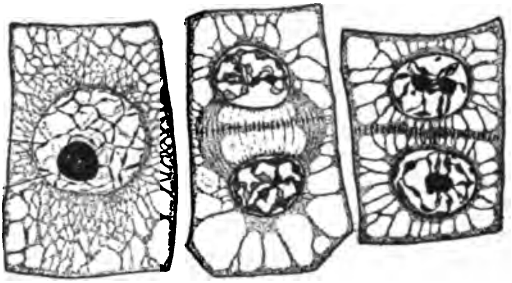
A, cell before division. *B*, cell with divided nucleus. *C*, single cell divided into two cells.

FIG. 4. — Cell division.

7. Cells of the blood. — If we were to examine with the compound microscope a drop of fresh blood,[1] we should find that it is not the simple red liquid it seems to be; it consists of solid particles, called *blood corpuscles*, floating in a watery liquid known as *blood plasma*. These corpuscles are single cells. Two kinds can be distinguished, which from their color are known as *red corpuscles* and *white corpuscles* (Fig. 5).

There are three hundred to seven hundred times as many red corpuscles as white. We shall first consider the white corpuscles. Each consists of a minute bit of protoplasm in which is imbedded a nucleus. These cells of the blood have a characteristic method of locomotion, in the process of which they change their shape; they can creep along in a direction opposite to that of the blood current, and they have even been seen forcing their way through the walls of small blood vessels by pushing out slender processes called false feet. They then wander about in the tissues of the body, and, as we shall soon see, do us great service. The white corpuscles closely resemble in structure and functions a kind of single-celled animal called the Amœba (**A. B.**,[1] Fig. 120).

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[1] The blood may be easily obtained by tying a cord tightly about the finger and then pricking it with a needle cleaned by an antiseptic like peroxid of hydrogen or by heating it in a flame. A drop of blood is squeezed out upon a glass slide and covered with a thin cover glass.

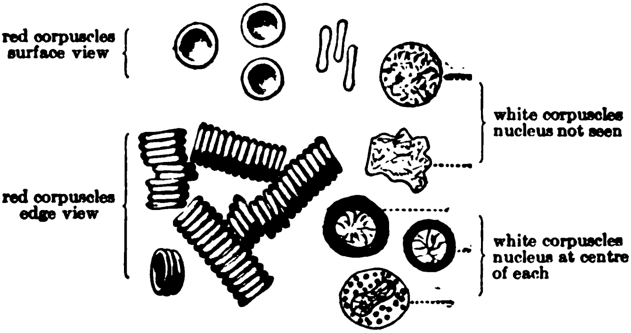
red corpuscles surface view
white corpuscles nucleus not seen
red corpuscles edge view
white corpuscles nucleus at centre of each

Fig. 5. — Cells of human blood.

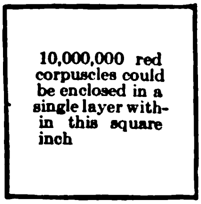
10,000,000 red corpuscles could be enclosed in a single layer within this square inch

Fig. 6. — Number of red corpuscles in a square inch.

The *red corpuscles* have no power of independent motion. They are circular disks, concave on both surfaces. Some idea of the minute size of these cells may be gained from the fact that ten millions of them would just about cover a space one inch square. There is no nucleus in the red corpuscles; they are, however, formed from cells having a nucleus.

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[1] **A. B.** = "Animal Biology."

8. Cells in other tissues. — It has been demonstrated that nerve tissue, muscle tissue, and other building materials of the body are all composed of cells (Fig. 3). *A tissue may now be defined as a building material of the body, composed of cells of the same kind.*

CHAPTER II

MICROÖRGANISMS AND THEIR RELATION TO HUMAN WELFARE

I. STRUCTURE AND FUNCTIONS OF BACTERIA

9. Bacteria:[1] their microscopical appearance and size. — In the preceding chapter we considered to some extent the organs, tissues, and cells of the human body. However, before we discuss further the structure and functions of these various parts of our bodies, we shall study in some detail certain microscopic plants which have a most intimate relation to human welfare. Chief among these are the tiny organisms known as *bacteria.*

Every one is familiar with the fact that if a bouquet of flowers is left for some time in a vase of water, the stems decay and disagreeable odors are given off. This is a common example of the action of bacteria, for all decay is due to the work of these organisms. When we come to examine the flower stems or the putrid water, we find a slimy scum. If we put a drop of this scum on a slide, cover with a cover glass, and examine with the highest powers of the microscope, we usually see many different forms of living things. Some of them appear relatively large, and these, as we have already seen (A. B., Chapter VI), are single-celled animals. A closer examination will disclose countless numbers of very minute, colorless organisms; these are the bacteria. A careful study of many kinds of bacteria shows that they have several characteristic shapes (see Fig. 7), by means of which they may be roughly classified. Some are rod-shaped (like a firecracker), some are spherical, or egg-shaped, and still others are spiral-shaped. *Each bacterium is a tiny bit of translucent protoplasm, inclosed in a cell wall of cellul'ose.* Thus far no nucleus has been discovered in any kind of bacteria. Because of their cellulose walls, and because of their likeness to certain low forms of green plants, biologists now regard these organisms as plants rather than animals.

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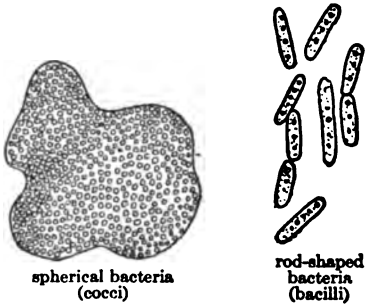
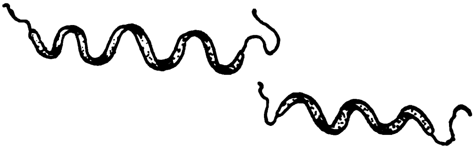
[1] The substance of this section, and several of those that follow, appear in Part I, "Plant Biology." Many teachers, however, find it impracticable to discuss bacteria until the work in human biology is taken up; hence the repetition of this material in this volume.

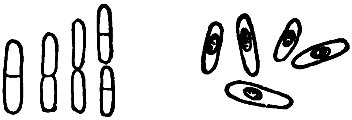


spherical bacteria (cocci)

rod-shaped bacteria (bacilli)



spiral bacteria (spirilla)



bacteria reproducing

bacteria with spores

Fig. 7. — Various forms of bacteria.

Some kinds of bacteria have one or more long, hairlike projections from the ends, called *cil'i-a,* which give the germs still further resemblance to firecrackers. These cilia lash about rapidly, and thus drive the cell through the water. The spiral bacteria roll over and over, and advance in a spiral path like a corkscrew.

It is very difficult to get any clear notion of the extreme minuteness of bacteria. It means little to say that the rod-shaped forms are $\frac{1}{5000}$ of an inch in length. The imagination may be somewhat assisted if we remember that fifteen hundred of them arranged in a procession end to end would scarcely equal the diameter of a pin head.

10. Microscopic study of bacteria. — Laboratory demonstration.

Place on a glass slide a drop of the scum found on the surface of a hay infusion, and cover with a cover glass. Examine with the highest powers of the compound microscope.

1. Describe the source of the material you are examining.
2. What is the apparent color of the tiny bodies (bacteria) that you see?
3. Which of the different forms of bacteria shown in Fig. 7 do you find? Draw enlarged figures of each of the shapes that you find.
4. Do any of the bacteria seem to be in motion? If so, describe the motion.

11. Reproduction of bacteria. — When conditions are favorable, the production of new cells goes on with marvelous rapidity. The process is something as follows: the tiny cells take in through the cell wall some of the food materials that are about them, change this food into protoplasm, and thus increase somewhat in size. The limit is soon reached, however, and the bacterium begins to divide crosswise into halves. The mother cell thus forms two daughter cells by making a cross partition (cell wall of cellulose) between the two parts (Fig. 7). If the daughter cells cling together, a chain or a mass is formed. Oftentimes they separate entirely from each other. In either case the whole mass of bacteria is called a *colony.*

It usually takes about an hour for the division to take place. Suppose, then, we start at ten o'clock some morning with a single healthy bacterium. If conditions are favorable, there would be two cells at eleven o'clock, and by twelve o'clock each of these two daughter cells would form two granddaughter cells; the colony would then number four individuals. Should this process continue for twenty-four hours or until ten o'clock on the day after the single bacterium began its race, the colony would number 16,777,216 bacteria. "It has been calculated by an eminent biologist," says Dr. Prudden,[1] "that if the proper conditions could be maintained, a rodlike bacterium, which would measure about a thousandth of an inch in length, multiplying in this way, would in less than five days make a mass which would completely fill as much space as is occupied by all the oceans on the earth's surface, supposing them to have an average depth of one mile."

12. Spore formation in bacteria. — Such startling possibilities as those suggested in the preceding section fortunately can never become realities, for favorable conditions soon cease to exist and the cells either die or cease to multiply. Sometimes, when food or moisture begins to fail, the protoplasm within each cell rolls itself into a ball and covers itself with a much thickened wall. This protects it until it again meets with conditions favorable for growth. The process we have been describing is known as *spore formation;* the tiny *protoplasmic* sphere is called a *spore,* and its dense covering a *spore wall* (Fig. 7). In this condition bacteria may be blown hither and yon as a part of the dust. They may be heated even above the temperature of boiling water without being killed. When at length they settle down on a moist surface that will supply them with food, the spores burst their thick envelope, assume once more their rod-shaped or spiral form, and go on feeding, assimilating, and reproducing their kind.

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[1] "The Story of the Bacteria," by Dr. T. Mitchell Prudden. G. P. Putnam's Sons, New York.

II. OCCURRENCE OF BACTERIA

13. Are bacteria present in the air. — Laboratory demonstration.

Materials: The best method of cultivating bacteria is by the use of a nutrient agar mixture in Petri dishes, which is prepared as follows: —

To prepare 1000 cc. (about a quart) of agar mixture, weigh out 10 grams of salt, 10 grams of peptone, 10 grams Liebig's beef extract, and 10 grams of agar. Measure into an agate stewpan 1000 cc. of water, and stir in the salt, peptone, beef extract, and agar (the latter having been cut into small pieces). Heat the mixture in a double boiler until the agar is wholly melted. Slowly stir in just enough baking soda to cause red litmus paper to turn blue; *i.e.* the mixture should be *slightly* alkaline. When the pieces of solid agar have all disappeared, the hot liquid should be filtered into flasks of 250 cc. capacity through several rather thick layers of absorbent cotton placed in a funnel. This filtration might well be done by placing the flasks in a steam sterilizer. If the filtrate is not clear, the liquid should be poured through the same layers of cotton till it does become clear. Care should be taken to keep the agar mixture hot during the filtering process, otherwise the agar will not pass through the cotton. When the flasks are nearly full, plug the mouth of each with a large wad of cotton batting, put them into a steam sterilizer, and heat them at least thirty minutes on each of three successive days to make sure that all germs and their spores are killed. The flasks of agar may then be kept as a stock mixture until needed.

Carefully clean and dry enough Petri dishes to supply, if possible, seventeen or more dishes for experiments with each division of students. Put the closed dishes in an oven and heat to a high temperature (150° C.) for an hour to kill any germs or spores that may be on the dishes. Allow the oven to cool before opening the door; otherwise the dishes are likely to crack.

To fill the Petri dishes, melt the agar mixture in a steam sterilizer, then arrange the sterilized Petri dishes along the edge of a horizontal surface. Carefully remove the cotton plug from the flask, lift one edge of the cover of one of the Petri dishes, pour enough of the hot agar mixture into the lower part of the dish to make a layer about an eighth of an inch deep, and quickly replace the cover on the dish. Quickly pour into each of the dishes in turn. After the agar has hardened, the dishes are ready for the experiments. Any agar mixture left in the flasks should be sterilized for thirty minutes on each of three successive days in order to make sure that it will keep for subsequent use.

Treat several of the Petri dishes of agar as follows: Label the first dish No. 1 and keep it closed throughout the experiments. Place a second Petri dish on the desk of a pupil, remove the cover and thus for ten minutes expose the surface of the agar to the air of a classroom or laboratory; label it dish No. 2. In a similar manner expose the surface of dish No. 3 for ten minutes to the air near the floor of a corridor through which classes are passing. Put all three dishes aside for a few days in a dark place where the temperature is 80° to 90° (*e.g.* in a furnace room), and then examine each dish.

1. State the difference in the treatment of dishes No. 1, No. 2, and No. 3. In what respects have all three been treated alike?
2. The spots on the surface of the agar are *colonies of bacteria*, each one of which has developed from a single bacterium (see Fig. 11). Which of the three dishes has the largest number of bacteria colonies?
3. Suggest a reason for the difference in the number of bacteria colonies in the three dishes.
4. What do you infer, therefore, as to the presence of bacteria in the air?

5. (Optional.) Make careful drawings at intervals of several days to show the difference in the number of colonies in the dishes, and the change in the size and appearance of the colonies.

14. Are bacteria present in water, milk, and other foods? — Laboratory demonstration.

Allow the water to run from the faucet for several minutes, and then spread a drop on the surface of dish No. 4. Spread a drop of milk on the surface of the agar in dish No. 5. On the agar surface of dish No. 6 put a bit of raw meat, a bit of apple peel, and bits of other kinds of food. Put the dishes in a warm, dark place as directed above, and examine at the end of several days.

1. State the difference in the treatment of dishes No. 4, No. 5, and No. 6.
2. In which of the three dishes do you find bacteria colonies? Describe the colonies in each dish as to position, number, and color.
3. What do you infer as to the presence of bacteria in water, milk, and other foods that you have tested?

15. Are bacteria present on various parts of the human body? — Laboratory demonstration.

Touch the surface of the agar in dish No. 7 with the finger tips; lay a hair on another part of the surface, and touch a third part with a toothpick that has been used to scrape the teeth. Put the dish in a warm, dark place as above, and examine at the end of several days.

Describe fully this experiment, stating your observations and conclusions.

16. Distribution of bacteria. — From our study of the culture dishes we have learned that bacteria are very common organisms. In fact, they are doubtless the most abundant of all living things; for they are found not only in air, water, and milk; not only in countless numbers wherever dead plant or animal material is allowed to accumulate; but also, unfortunately, in living tissues.

17. To determine conditions favorable and unfavorable for the growth of bacteria. — Laboratory demonstration.

A. The effect of different degrees of temperature. — Expose for ten minutes three Petri dishes of nutrient agar to the air in a room or corridor when classes are moving about. Cover the dishes and label them No. 8, No. 9, and No. 10, respectively. Put dish No. 8 in a temperature of 80° to 100° F., and dish No. 9 in the refrigerator, or in some other equally cold place. Dish No. 10 should be put in a steam sterilizer and heated for thirty minutes on each of three successive days; it should then be kept in a warm, dark place.

1. Describe the difference in the treatment of dishes 8, 9, and 10.
2. At the end of a week examine each of the three dishes. What difference do you find in the relative number of colonies in them?
3. What do you conclude, therefore, as to the influence of each of these three different degrees of temperature on the growth of bacteria?

B. Pasteurization of milk. — (Optional.) If possible secure a Pasteurizer[1] (Fig. 8). Carefully clean with soap and hot water, inside and out, four of the glass bottles, fill each with milk that is fresh, and fasten on the stoppers.

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[1] *Home Pasteurizers,— System Nathan Straus,* —each supplied with bottles and stoppers, may be bought at the Nathan Straus Pasteurized Milk Laboratory, 348 East 32d St., New York City, or at any of the Laboratory depots situated throughout the city. The manufacturer's price for the entire outfit is $1.50. The authors are indebted to the Nathan Straus Laboratories for the cut of the Pasteurizer, and for the directions quoted above. The circular also contains the following statements. "The advantage of Pasteurization over other systems, such as sterilization or boiling, consists in the lower degree of heat applied, which is sufficient to kill all noxious germs, while the nourishing quality and good taste of the milk are retained. . . . Before use, warm the milk — in the bottles — to blood heat. Never pour it into another vessel. The milk must not be used for children later than twenty-four hours after Pasteurization. Never use remnants."

Keep one bottle at the temperature of the laboratory, labeling it bottle No. 1, and put another, bottle No. 2, in the refrigerator. Pasteurize the other two bottles in accordance with the following directions: —

"Set the bottles into the tray. . . . The pot is then placed on a wooden surface (table or floor) and filled to the three supports (in the pot) with boiling water. Place the tray

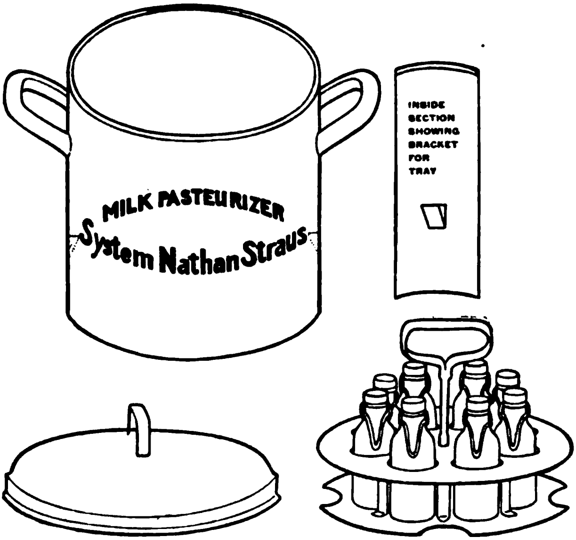

Fig. 8. — Straus Pasteurizer.

with the filled bottles into the pot, so that the bottom of the tray rests on the three supports, and put cover on quickly. After the bottles have been warmed up by the steam for five minutes, remove the cover quickly, turn the tray so that it drops into the water. The cover is to be put on again immediately. This manipulation is to be made very quickly, so that as little steam as possible can escape. Thus it remains for twenty-five minutes. Now take the tray out of the water, cool the bottles with cold water and ice as quickly as possible, and keep them at this low temperature till used."

Place one bottle of Pasteurized milk (No. 3) beside the bottle in the room temperature, and the other (No. 4) in the refrigerator beside bottle No. 2.

1. At the end of three days shake the two bottles kept at the room temperature and open them. Smell or taste of the milk in each. State your observations and conclusions.
2. In a similar manner, test the two bottles that have been kept on ice for a week. State your observations and conclusions.
3. Why are milk, meat, and other foods of the kind put into the refrigerator, especially in summer time? Does this kill the bacteria? How do you know?
4. Why are meats cooked, milk Pasteurized, and fruits boiled before they can be kept for any length of time?

C. The effect of lack of moisture.—Expose for ten minutes two Petri dishes of nutrient agar in a dusty room or corridor (as in *A* above). Place the two dishes (No. 11 and No. 12 side by side in a warm room (over 90°). Cover dish No. 11 and leave dish No. 12 uncovered.

1. Describe the similarity and the difference in the treatment of dishes 11 and 12.
2. How is the agar mixture affected by removing the cover?
3. In which dish do colonies of bacteria develop?
4. What do you conclude, therefore, as to the necessity of moisture for the growth of bacteria?
5. Why is hay dried before it is put into the barn? Name some foods used by man that are kept for a long time after being dried.
6. As a conclusion from these experiments (in *A*, *B* and *C*) state what conditions you have found favorable for the growth of bacteria.

7. State also what conditions you have found that hinder the growth of bacteria.

D. *The effect of antiseptics.* — Prepare a *pure culture* of bacteria in dish No. 13 in the following manner. Heat a dissecting needle on a piece of platinum wire in a hot flame to kill all the germs upon it. When it cools, touch a colony of bacteria in a Petri dish with the needle-point or wire; carefully raise the cover of dish No. 13 and make several scratches in the agar (the date of the experiment or the number of the room may be scratched in this way). In a similar way prepare dish No. 14 and then pour over the surface some peroxid of hydrogen or other antiseptic solution. When the dishes have been treated as described above, put them in a warm, dark place for several days.

1. Describe the preparation of dishes 13 and 14.
2. In which of the two dishes do you find no colonies of bacteria at the end of several days?
3. Peroxid of hydrogen is employed in treating wounds. What reason have you for thinking bacteria would be killed by this treatment?

III. BACTERIA AS THE FRIENDS OF MAN

18. Relation of bacteria to soil fertility. — Having discussed somewhat the structure and functions of bacteria, we are now to consider the great importance of these microscopic organisms to human welfare. In the first place, were it not for their never ending activity, all life upon the earth would soon cease to exist. Let us see why this is so. When animals or plants die, their bodies fall upon the ground, and had not these lifeless masses been taken care of, the whole surface of the earth would long since have been covered with a vast number of unburied organisms. All this dead material, however, as we have seen, is food for the countless bacteria; they cause it to decay, and thus decompose it into simpler chemical compounds that soak into the earth and may then be used in the nutrition of the higher plants. And since plants are constantly taking from the soil the food materials that they need, this soil would tend to become less and less fertile were it not for the work of the bacteria that cause decomposition. This is the reason why rotting manure adds to the fertility of soil.

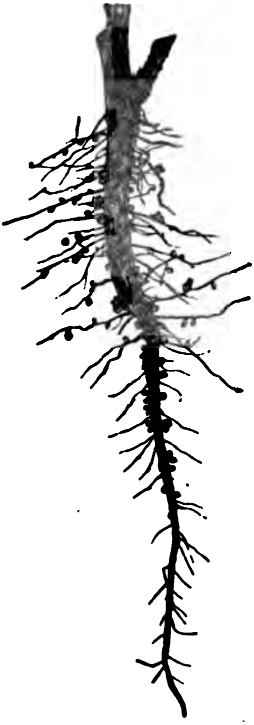

Fig. 9. — Roots of horse bean, with tubercles.

Again, it has been proved that certain kinds of bacteria directly increase the amount of nitrogen compounds that are so essential for plant growth. It has long been known that corn and other crops will grow better in soil that has just borne a crop of peas, beans, clover, or other members of the pea family. Within recent years an explanation of this fact has been found. When the roots of these pod bearing plants are examined, small swellings are seen (Fig. 9). These contain multitudes of bacteria that are able to take the free nitrogen from the air, where it exists in such abundance, and store it away in the form of nitrates, which are very important mineral matters needed by all crops. Since these bacteria can be put into soils that do not have them, it may be possible in the near future to restore much of the fertility that has been lost (Fig. 10).

19. Relation of bacteria to the flavors of food. — Again, many of the flavors of food are due to the action of bacteria. The flesh of animals, for instance, that have just been killed, is often tough and tasteless. If allowed to stand, however, these meats become tender and acquire their distinctive flavors by the decomposing action of bacteria. A similar action takes place when butter or cheese ripens, and the dairy industry has been perfected to such a degree that bacteria of certain kinds have been proved to give rise to definite flavors, and these bacteria may be produced in pure cultures for the dairymen.

FIG. 10. — Bacteria from root tubercles.

20. Bacteria in the industries. — Without the help of bacteria the preparation of linen, jute, and hemp would be impossible. All these valuable products are plant fibers which are connected with woody materials so closely that they cannot be separated without first subjecting the stems of flax, hemp, and jute to a process of decay in large tanks of water. Moisture and warmth induce the rapid growth of germs, and the resulting decay loosens the tough fibers so that they may be separated from the useless parts of the plant. The change of alcohol into vinegar is also caused by bacteria. Formerly in the preparation of indigo other forms of bacteria were all-important, but at the present time indigo is largely made artificially.

IV. BACTERIA AS THE FOES OF MAN

21. Injurious effects of bacteria. — Most of the common bacteria are either harmless or distinctly beneficial to mankind (**18–20**). The experiments we tried with milk (**17**, *B*), however, show that this kind of food soon sours unless it is kept in a very cold place. Every housekeeper knows also that meat and many other kinds of food quickly spoil if they are not cooked or otherwise preserved. In a following section we shall consider some of the methods that are used to prevent this decaying action of bacteria.

Unfortunately, too, there are certain germs[1] that find favorable conditions for growth in living animal tissue, and by their growth cause certain diseases, some of which are tuberculosis, diphtheria, and typhoid fever. In later sections we shall learn that these disease-producing bacteria are all too common in dust, water, and foods; but we shall likewise see that scientists are fast learning effective methods of *preventing* the ravages of these disease-producing bacteria, which are called by Dr. Prudden " Man's Invisible Foes." [2]

22. Methods of food preservation. — We saw in (**17**, *A* and *C*) that bacteria thrive whenever they can get plenty of food and moisture, and whenever the temperature is favorable for their growth. We also learned that, whenever any one of these necessary conditions is wanting, bacteria cease to carry on their functions. If, then, we wish to keep food from spoiling, we need only to bring about conditions that are unfavorable for the growth of microörganisms.

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[1] Disease-producing bacteria are commonly spoken of as *germs* or *microbes*.

[2] In general it is unwise and unnecessary that boys and girls should be taught much regarding the symptoms and effects of disease; but since so much may be done to *prevent* these diseases that we have mentioned and others that afflict mankind, it is essential that the young should learn something of the deadly work of some of the germs which are all too common.

For instance, everybody knows that meat, milk, and eggs must be put on ice in summer if they are to be kept for any length of time. Indeed, many food materials of this sort will remain in a more or less fresh condition for months or even years if they are in cold storage. It has been proved, however, that food products kept in cold storage for a long time are often unsafe for human consumption. On the other hand, we demonstrated (**17**, *A*) that a high degree of heat will kill bacteria, and so meats that have been cooked and milk that has been Pasteurized or scalded will keep longer than they do when left uncooked. If meats, vegetables, or fruits are heated to the boiling point in cans and sealed up at once, they may be permanently prevented from spoiling.

Ham and herring are often smoked to preserve them, while pork and codfish are soaked in a strong solution of salt (brine) to keep them from the decaying action of bacteria. Another method of preserving food is by depriving it of water. Dried beef, apples, hay, and seeds will keep indefinitely if no moisture is allowed to get to them. Previous to the passage of the Pure Food Law by Congress in 1906, many unscrupulous dealers were accustomed to use borax, formaldehyde,[1] and other chemicals to prevent their food supplies from spoiling. Fortunately for the health of the consumer, this method of food preservation has been largely stopped by the enforcement of the law to which we have just referred.

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[1] *Method of determining whether or not formalin has been added to milk.* Into each of two test tubes or flasks put an equal quantity of fresh milk. To one of the glasses add a drop or two of formaldehyde solution. Then to each add a volume of hydrochloric acid equal to

23. To determine the best method of cleaning a room. — (Optional Demonstration.)

Select three rooms with rugs or carpets as nearly as possible of the same size and amount of dirt. Open Petri dish No. 15 and expose its surface for five minutes at the level of the table while one of the three rooms is being swept with a broom. In a similar manner expose the surface of dish No. 16 for five minutes to the air in a room that is being cleaned with a carpet sweeper, and dish No. 17 in the third room for five minutes while it is being cleaned with a vacuum cleaner. Close each of the dishes, label, and put in a warm place (90° to 100° F.) for several days.

1. Describe the preparation of dishes 15, 16, and 17.
2. What difference do you find in the relative number of bacteria colonies in the three dishes?
3. What do you conclude, therefore, as to the most effective method of removing dust and germs from a room?

24. Proper methods of sweeping and dusting. — From our experiments (**13**, **23**) we have learned that large numbers of bacteria are present in the air of rooms where dust is raised by the movement of people or by sweeping. Since each colony started from a single bacterium, it is easy to show the relative number of germs present in the air under varying conditions (Fig. 11).

The number of bacteria that may be found in a church, schoolroom, theater, or living room has been proved by a

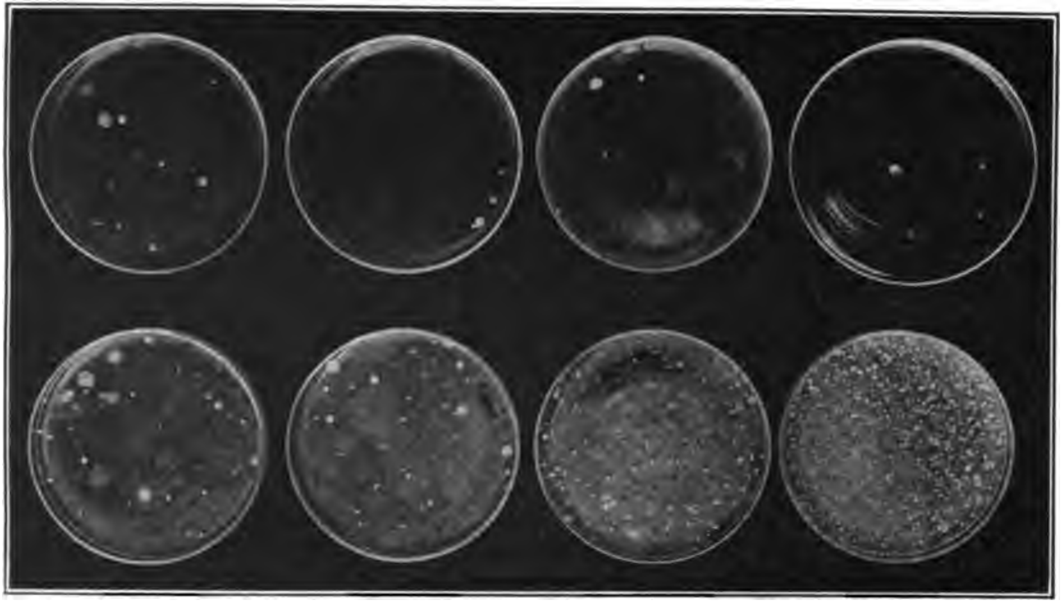
that of the milk and a drop of ferric chloride (made by dissolving a spoonful of ferric chloride in a quart of water). Put both dishes of milk into a dish of boiling water and stir or shake frequently for five minutes.

1. Describe the preparation of the experiment.
2. At the end of five minutes state the color produced in the milk in each of the two test tubes.
3. How, then, can you determine whether or not formalin has been added to milk?

long series of experiments to be enormous, for with the ordinary methods of "cleaning" these rooms, very few of the germs are removed. When a room is swept, most of the light dust particles are raised from the floor and mingled with the air. After a short time the room is "dusted," often with a feather duster. The bacteria which may have settled are whisked off again into the air. Experiments have shown, too, that the number of germs in a room is not materially diminished by ventilating currents, unless there is a strong draught.

Most of this germ dust can, however, be removed from our homes if they are cleaned in a proper manner. In a room that has not been used for three or four hours practically all of the bacteria and fine dust particles have settled out of the air upon the horizontal surfaces. For dusting, a cloth should always be used. "Dustless dusters" may be bought or prepared by soaking a piece of cheesecloth or flannel in a mixture of wax and turpentine, or by slightly sprinkling cheesecloth with water. By the use of these cloths most of the particles of dirt may be taken up and then removed from the cloths by washing. If carpets, rugs, and draperies are then cleaned with a vacuum cleaner, practically no dust is raised (Fig. 11); hence, further dusting is unnecessary. Careful investigation has demonstrated that the use of a vacuum cleaner on surfaces that may be washed or wiped with a cloth is too expensive a method of cleaning, and that it is not nearly as effective.

It is much more hygienic to have floors covered with rugs, for if a vacuum cleaner is not available, the dusty rugs and draperies may be removed from the room and cleaned in the open air. In general, a carpet sweeper is to be preferred to a broom as a means of cleaning carpets, since, as Fig. 11 shows, fewer germs are stirred up when the former is used.



A. Vacuum cleaner experiment.

B. Carpet sweeper experiment.

C. Wet paper and broom experiment.

D. Dry broom experiment.

FIG. 11.—Upper row of dishes show bacteria colonies before sweeping; lower row, after sweeping. See footnote on p. 28. (Photographed by Mr. E. R. Sanborn, N. Y. Zoölogical Park.)

If brooms are used, small pieces of crumpled newspapers or tea leaves should be moistened and scattered on the floor before the sweeping is done.[1]

In cleaning public buildings, the floors should first be sprinkled with moist sawdust and then the coarser dirt collected by brushing with hair brooms. The floors should then be washed each day if possible.[2] Dirty streets, too, are a constant source of dust infection. Most of the irritation and possible diseases from this source would be avoided,

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[1] Figure 11 shows, so far as bacteria are concerned, the comparative results obtained by four methods of sweeping. Four rugs of the same size and approximately the same amount of use were selected, and placed at night in four different rooms. Early the next morning a Petri dish was uncovered in each room, and thus the nutrient agar of each dish was exposed to the air of the room for five minutes; after which the dishes were covered.

A second set of four dishes was then opened in turn for five minutes while the four rugs were being cleaned as follows. Rug D was swept with a dry broom; rug C was covered with pieces of wet newspaper and then swept with a broom; rug B was cleaned with a carpet sweeper; and rug A was cleaned with a vacuum cleaner.

All of the eight dishes were then closed and kept in a warm room for five days and at the end of that time were photographed. (See Fig. 11.) The number of bacteria colonies in each dish were counted, and the results are expressed in the following table:

	No. Colonies before Sweeping	No. Colonies after Sweeping	No. Times Colonies were increased by Sweeping
Dish D	4	1190	297+
Dish C	6	436	72+
Dish B	7	135	19+
Dish A	25	118	4+

Hence over four times as many bacteria were stirred up by a carpet sweeper as by a vacuum cleaner, eighteen times as many when the sweeping was done with a broom and wet paper, and *over seventy times as many when a dry broom was used.*

[2] We are indebted to Mr. John H. Federer, Superintendent of the New York Public Library building, for valuable information contained in the preceding paragraphs.

however, if the citizens insisted that the streets be kept watered, especially when they are swept. Street sweeping and the removal of garbage should be done as far as possible at night.

25. Treatment of cuts. — A vast amount of discomfort and possible danger from bacterial infection in the body would be avoided if people but used proper care in the treatment of wounds. We have seen that white corpuscles resemble amœbæ in their structure and activities (7). Let us now study their functions in the human body. When one gets a sliver of wood in one's finger and leaves it there for a time, the finger becomes more or less swollen and sore, and white "matter" or *pus* usually forms in the region of the wound. These effects are principally due to the activity of bacteria, which were carried into the wound on the piece of wood. Finding in the tissues all the favorable conditions for growth, these minute organisms multiply rapidly and produce poisons called *toxins*, that cause the inflammation.

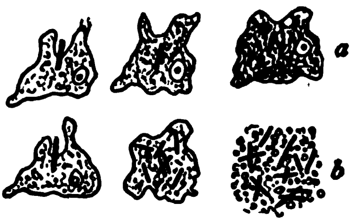

FIG. 12. — White corpuscles.

a — a white corpuscle devouring a bacterium.
b — a white corpuscle destroyed by bacteria.

As soon however, as these inflammatory processes begin, large numbers of white corpuscles are hurried to the spot and proceed to attack the invading bacteria. If the number of germs is relatively small, and if the corpuscles are in a healthy condition, these cells of the blood seize upon and devour the bacteria (Fig. 12) in the same way that an amœba takes in its food. Under these conditions little if any pus is formed. But if the bacteria get the upper hand in the struggle, many of the corpuscles are killed, and it is the dead white corpuscles that form the pus.

FIG. 13. — Dr. Robert Koch, German bacteriologist. Born 1843. Died 1910.

(From International Encyclopedia. Courtesy of Dodd, Mead & Co.).

In case of a cut the wound should be cleansed as quickly as possible with peroxid of hydrogen or some other germ-destroying solution, and should then be covered with absorbent cotton soaked in the peroxid solution and bandaged, to prevent the entrance of other germs. If this is not done, bacteria are likely to settle in the wound, and healing may be delayed or even more serious results may follow. With proper treatment a wound should show no signs of inflammation, or formation of pus, and should heal rapidly.

26. The cause of tuberculosis. — It is said that one seventh of all the deaths in the world are due to the disease tuberculosis, which is more commonly known as *consumption.* In New York City alone the Board of Health reports 300 to 400 new cases every week. Yet if the general public only knew the manner in which this disease is transmitted and would make use of this knowledge, the dreadful sacrifice of life and health due to this "great white plague" could be almost wholly prevented.

It was conclusively proved in 1882 by Dr. Koch, a noted German scientist (Fig. 13), that tuberculosis is always caused by extremely small, rod-shaped bacteria, *bacillus tuberculosis* (Fig. 14). He found countless numbers of these living germs in the sputum coughed up by consumptive patients; he cultivated these germs in test tubes and when he injected the bacteria into the bodies of guinea pigs or rabbits, the animals became ill with tuberculosis. By many experiments of this sort, biologists have learned important facts in regard to the cause, prevention, and cure of disease.

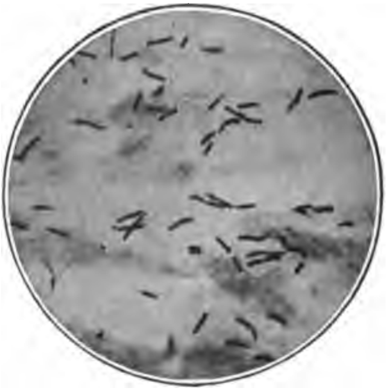

Fig. 14. — Tuberculosis bacteria in human sputum. (Courtesy of Dr. Thomas S. Carrington.)

We are absolutely sure then, that before any one can become a consumptive, he must take into his body the living bacteria of consumption, and the most common avenue of infection is through the nose and air passages. Consumptives who are ignorant of the danger they are causing, frequently expectorate on the floors of rooms or of public conveyances, and when this sputum becomes dried, the germs are likely to be blown about in the air, and to be inhaled by other people. When the bacteria get into the lungs of a person who happens to be a little "run down," as we say, straightway the bacteria begin to multiply, feeding meanwhile on the lung tissues; for this reason the disease is called consumption, and if it is not arrested, the lungs may be almost destroyed, and death, of course, results. During the progress of the disease, little masses or *tubercles* of lung tissue (whence the name *tuberculosis*) are thrown off by the patient in coughing, and these, as we have already stated, are swarming with living bacteria.

27. The prevention of tuberculosis. — It is of the utmost importance, therefore, that these living germs be kept out of the bodies of people who come in contact with consumptives. Responsibility in this matter rests very largely upon the patients themselves, and if they exercise the necessary care, they need not become a menace to healthy people in the home or in the community. It is of course essential that every effort be made to stop altogether the dirty and dangerous habit of spitting. Many people have the disease long before they are aware of it, and a general public sentiment should be developed that will actively assist boards of health in enforcing their rules against the "spitting nuisance." Every consumptive should provide himself with paper cups or cloths that may be burned, together with their contents.

Tuberculous patients should exercise care not to cough or sneeze without covering the mouth or nose with a handkerchief, for it has been proved that living germs are widely distributed by carelessness in this regard. Separate knives, forks, spoons, and drinking vessels, which ought to be cleaned in boiling water, should be set apart for consumptives. Kissing the lips of consumptives should never be permitted.

28. The cure of tuberculosis. — In former years the decision by doctors that a patient had tuberculosis was believed to be a sentence to a lingering death; it was believed also that the disease was hereditary. Happily modern medicine has dispelled both these beliefs. A child may inherit weak lungs or a frail body; but it will never be a consumptive unless the bacteria that cause this disease are in some way planted in his tissues. Consumption, too, is a curable disease, unless it is neglected until it has reached an advanced stage. The prime requisites in the treatment of the disease are a plentiful supply of fresh air, plenty of easily

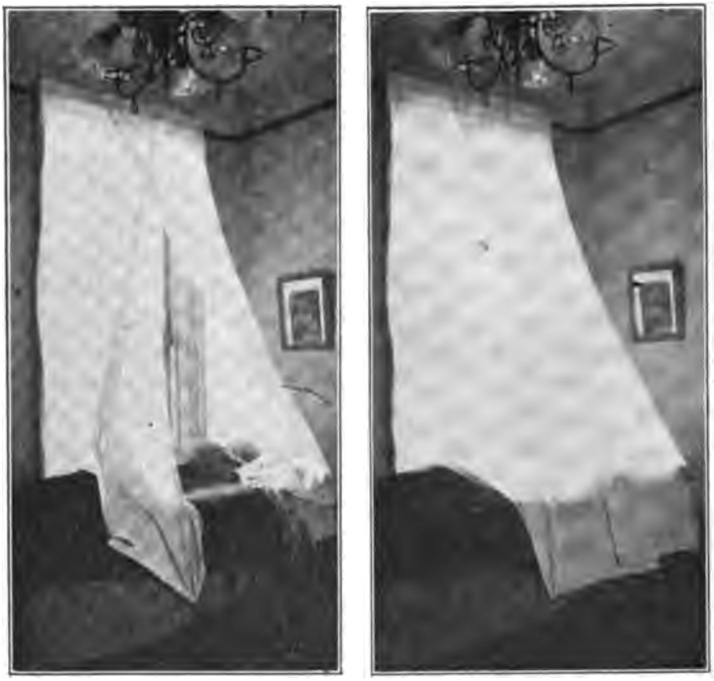
A. Tent open. *B.* Tent closed.

FIG. 15.—Window tent. (Courtesy of Dr. Thomas S. Carrington.)

digested and nutritious food, like eggs and milk, sleep and freedom from hard muscular work and from worry. These conditions may be obtained even in crowded cities, for by the use of tents on the roof, or of window tents (Fig. 15) a sufficient amount of air may be secured, and almost marvelous cures are found to result.[1]

29. The cause and treatment of pneumonia. — Another disease that affects the lungs is *pneumonia*. It is more prevalent in the spring and autumn of the year, and is commonly a disease of adults. The cause of pneumonia is a spherical form of bacteria, which get into the lung tissue and grow there when the individual is physically weak or mentally depressed. Formerly, in treating the disease, patients were kept in closed rooms, carefully shielded from all draughts of air. It has been found, however, as is the case with tuberculosis, that fresh outdoor air is one of the best means of treating the patient. To combat both tuberculosis and pneumonia, our bodies and minds should be kept in such a healthy and vigorous condition that invading disease germs will always meet with a hostile reception whenever they attempt to prey upon our organs and tissues.

30. Cause of diphtheria. — Another disease that formerly claimed many victims among young children is *diphtheria*. The germs of this disease are rod-shaped organisms somewhat larger than those that cause tuberculosis. When these bacteria find lodgment and grow in the throat, they produce a membrane and form poisonous substances known as *toxins*, which are absorbed and carried by the blood to other parts of the body, often causing paralysis and other injurious effects.

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[1] The authors are much indebted to Dr. Thomas Spees Carrington for suggestions relating to tuberculosis. For additional suggestions see Dr. Carrington's "Fresh Air and How to Use It" ($1), National Association for the Study and Prevention of Tuberculosis, 105 E. 22d St., New York City.

31. Treatment of diphtheria. — But these germs do not have things all their own way. The cells of the body seem to know when an army of this enemy has entered their territory, and they at once set to work to produce substances that will neutralize or overcome the toxins formed by the diphtheria bacteria; these substances are known as *antitoxins*. When the disease is at its height, there is a fierce battle between the invading microbes with their toxins and the cells of the body fighting for their lives by means of their antitoxins. If the bacteria are victorious, death ensues.

In the year 1892 a most important discovery was made by a German bacteriologist named Von Behring. He found that it is not necessary for the human body to manufacture all the antitoxin it needs for its struggle with the diphtheria poisons, but that this substance may be taken from the blood of other animals that have produced it. For this purpose, healthy horses are now secured by city boards of health, and a small dose of diphtheria toxin is injected into their bodies; the next day a larger dose may be given with little or no ill effects; until, at the end of several months of this treatment, the animals can stand a quantity of the poison that would have proved fatal if given at an earlier time. For during all these days the horse has been having a very mild form of diphtheria, and the cells of his body have been producing and giving into the blood an amount of antitoxin much more than is needed to neutralize the diphtheria poisons the animal has received. Some of the blood is then carefully removed and allowed to clot. The liquid *serum* that oozes out of the clot contains the antitoxin, which is carefully prepared for injection into the body of human beings when diphtheria attacks them. And so our good friend the horse, without any permanent ill-effects to himself, has decreased the death rate formerly caused by diphtheria by 75 to 80 per cent.

32. Prevention of diphtheria. — We have learned something of the means by which we can combat this disease when once it has begun its attack. Antitoxin may also be administered to any members of the family who have been exposed to diphtheria, and it then becomes a means of preventing the disease. But it is much more important, as is the case with tuberculosis, to prevent all danger from attacks by this disease than it is to know how to cure it. Here again we find strong arguments for the enforcement of the rules against spitting, for living bacteria are often found in the throats of sufferers from what are thought to be ordinary sore throats. For this reason, too, children should be especially careful to avoid putting into their mouths pencils, coins, candies, or other objects that have been used by other pupils, for diphtheria germs have been frequently transmitted in this manner.

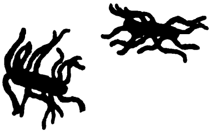

FIG. 16. — Typhoid bacteria.

33. Cause of typhoid fever. — Typhoid fever is a disease caused by the growth in the tissues of the intestines of rod-shaped bacteria. The typhoid bacteria have several hair-like projections something like long cilia (known as *flagella*), which vibrate rapidly and so enable the germs to move about (Fig. 16). These bacteria are practically always taken into the body through the mouth and thence into the intestines. "Food and drink are usually the vehicles which serve for the entrance of the bacillus, water and milk being probably the most frequent sources of infection. The latter is especially dangerous from the fact that the typhoid bacillus not only lives but multiplies in it. Water and milk, however, are only dangerous when they actually contain the typhoid bacilli which have entered into them from the excretions of typhoid patients or those who have become typhoid carriers."[1] It has been proved over and over again that the common house fly is frequently the means by which typhoid fever is transmitted (A. B., 43), since these insects often alight on the excretions of typhoid patients, and then carry the germs on their hairy feet (A. B., Fig. 40), and so infect the foods on which they alight.

34. Prevention of typhoid fever. — It is evident, then, that if the excretions from the intestines and kidneys of typhoid patients were thoroughly disinfected by carbolic acid or other germicides, the spread of typhoid fever would be very largely prevented. It must be borne in mind, however, that the bacteria of this disease continue to live in great numbers and to multiply in the intestines of some people who have had typhoid fever years after recovery from the disease, and these people are the so-called "typhoid carriers."[2]

One of the most difficult problems that formerly confronted armies was that of preventing typhoid infection. In the Mexican War and in the Civil War the armies on both sides paid frightful toll to this dread disease, and even in the Cuban War, five thousand men in the United States Army died of typhoid fever or other fly-borne diseases, while only three hundred were killed by Spanish bullets. Sanitary camps, however, have greatly improved the situation, and in recent years an anti-typhoid vaccine, somewhat like that used in the prevention of smallpox, is injected as a means of prevention, and the results of the use of this vaccine have been most favorable. The improvement in army health is strikingly shown by comparing figures for two army divisions of about the same size, one at Jacksonville, Florida, during the Spanish-American War in 1898, the other at San Antonio, Texas, during the 1911 maneuvers on the Mexican border.

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[1] Quoted from article on typhoid fever, in New International Encyclopedia, copyrighted 1903 by Dodd, Mead, and Co.

[2] See footnote, p. 39.

	JACKSONVILLE 1898	SAN ANTONIO 1911
Number of soldiers	10,759	12,801
Number cases typhoid (certain and probable)	2,693	1
Number of deaths from typhoid fever	248	0
Number of deaths from all diseases . .	281	11

35. Water supplies. — In country districts each house usually has its own well, and so the family becomes accountable for its own water supply. In this case great care should be taken to place the well in such a position that none of the drainage from the house or barn can soak through the soil into the well-water. Those who live in large towns and cities almost always obtain their water supply from a common source. This sometimes becomes contaminated by typhoid and other germs, and a disease epidemic then follows. Hence, if there is any doubt as to the purity of a water supply, boards of health should notify the householders, and the water, when used for drinking purposes, should then be boiled and kept in bottles on ice until used.

36. Milk supplies. — Many families in rural communities keep their own cows, and so they can be sure of clean milk if they only take the necessary trouble. Cows, like human beings, need plenty of light, air, wholesome food, and clean surroundings. If any of these are wanting, the animals are likely to become diseased, and the milk is then affected. Great care should be taken also at milking time to see that the surface of the body of the cow, especially about the flanks and udder, are brushed and wiped with a moist cloth, and that the hands and clothing of those who milk are kept clean; otherwise enormous numbers of microbes will fall into the milk. No one who has any infectious disease should be allowed to have anything to do with the care of cows or of milk until he has completely recovered. Over and over again epidemics of diphtheria, scarlet fever, typhoid,[1] and tuberculosis in infants have been traced along the routes of careless milkmen.

Those who live in cities, however, are wholly dependent for milk upon sources they know nothing about. The milk that is consumed in New York City, for instance, comes from over 40,000 dairies scattered through six different states. It is, of course, impossible to make any proper inspection in such a wide field. The New York Board of Health is doing all it can in this respect, and so far as possible it prevents dirty and dangerous milk from coming to the city. The only path of safety, however, lies in the careful Pasteurization of milk and cream that are used for drinking purposes, especially by young children. In communities where Pasteurization has been tried at all generally, there has been a surprising decrease in the percentage of sickness and death from intestinal diseases, especially in the summer time and among young children. The instruction given by boards of health to mothers and to older children as to the care of the young during the hot months has also helped to save the lives of a large number of infants.

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[1] A sudden increase in the number of cases of typhoid fever in New York City in 1909 was found to be entirely due to milk furnished by a dairyman in a town in New York State. He had recovered from typhoid fever in 1864, but still carried infection in his body and passed an enormous number of the germs of the disease.

FIG. 17.—Dr. Edward Jenner, English physician. Born 1749. Died 1823.

(From International Enclyclopedia. Courtesy of Dodd, Mead & Co.).

37. Smallpox and vaccination.—Smallpox was once so common that scarcely one person in a hundred escaped it. It was introduced into America by the Spaniards, it destroyed 3,500,000 people in Mexico, and spread with frightful rapidity throughout the New World, until in 1733 it nearly depopulated Greenland. Mankind is indebted to Dr. Edward Jenner (Fig. 17), an English physician, who in 1796 proved that vaccination is a sure method of preventing the disease. In vaccination our bodies receive germs that originally came from smallpox, but which have been so modified that they cause a mild form of disease very different from smallpox itself. The cells produce some form of antitoxin which is effective protection when we are exposed to the disease. This kind of protection does not last indefinitely, however, and every person should make sure that successful vaccination is performed at least once in ten years, and oftener than that if cases of smallpox develop in the community in which he is living. If a person has been actually exposed to the disease, he should be vaccinated immediately.

Since the introduction of compulsory vaccination, smallpox is becoming very rare.

38. Hydrophobia and the Pasteur treatment. — Hydrophobia, or rabies, is a disease due to the bite of a mad dog, cat, or wolf. Until the latter part of the nineteenth century the only known method of treating this disease was that of burning out or cauterizing the wounds with hot irons or nitric acid. After a long series of investigations, however, Louis Pasteur (Frontispiece), a French scientist, made known to the world the so-called Pasteur treatment (1885). Pasteur found that the disease was located in the spinal cord, and that, if pieces of the spinal cord of a rabbit which had died of hydrophobia are allowed to dry in the air, the germs gradually lost their virulence. He therefore began the treatment of patients who had been bitten by mad dogs by first injecting beneath the skin an emulsion made from the spinal cords which had been dried for fourteen days. Each day for twenty-one days an injection was made from a cord that had been dried for a shorter time. Since hydrophobia usually does not develop in human beings for two weeks to four months after the bite of a mad dog, the cells of the body by this Pasteur treatment gradually acquire the power to resist the hydrophobia toxins, and so the disease is prevented, if the wound is cauterized at once and treatment begun immediately. The cauterization is of value even after a delay of twenty-four hours.[1]

39. The cause and prevention of other diseases. — The germs that cause scarlet fever, yellow fever, measles, whooping cough, and infantile paralysis have not as yet been discovered. Since, however, they are all infectious diseases like tuberculosis and diphtheria, they must be due to some form of microbe. Those in yellow fever, measles, and infantile paralysis are so small that they pass through stone filters.

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[1] The authors are much indebted to Dr. W. H. Park, Director of the Laboratory of the Board of Health of New York City, for his suggestive criticism of the sections relating to disease-producing bacteria.

These cells are therefore too small to be seen by the most powerful microscopes.

The life history and method of transmission of the microscopic animal that causes malaria has already been discussed in connection with the study of the Anopheles mosquito (A. B., 40). Likewise, it has been demonstrated beyond a cavil that infection from a yellow-fever patient can only be brought about through the agency of the Stegomyia mosquito. Hence, to eradicate these diseases entirely, we need only to exterminate all Anopheles and Stegomyia mosquitoes. Sleeping sickness is a dread disease of the tropics which is due to a kind of Protozoan something like a paramecium.

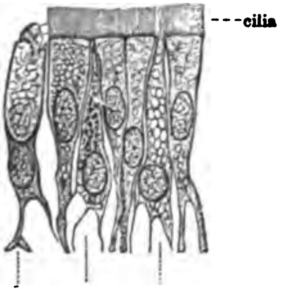

FIG. 18. — Ciliated cells from the windpipe.

40. Safeguards of the body against disease. — In the first place, the tough outer skin, as long as it is unbroken, forms a most effective barrier to the entrance of bacteria, except at the mouth and nose openings. Each of the nostrils is guarded by hairs that collect a large number of dirt particles. On the mucous membrane lining the nose and throat still other bacteria are caught, and the cells which line the windpipe are furnished with cilia, which lash upward (Fig. 18) and tend to expel the germs that may have gone past the outer lines of defense that we have named. If the bacteria enter the stomach and intestines in a living condition, many of them are digested with the food. And even though the invading microbes finally reach the interior of the cells of our lungs, or muscles, or brain, we can still rely upon the antitoxins which the cells of a healthy human body are ever ready to produce. In the case of many of the contagious diseases, like scarlet fever or smallpox, these antitoxins remain for a considerable time in the blood to make us immune against a second attack. The white corpuscles, too, are a sort of cavalry troop, ready to pounce upon the bacteria and either devour them or carry them off from the body (Fig. 12, *A*). An optimistic view of life and freedom from worry are undoubtedly very important factors in keeping the body in a state of vigorous health.

41. Topics for biology composition.[1] — Optional Library Work. Consult the local health authorities, Allen's "Civics and Health," Bulletins of U. S. Department of Agriculture, New International or other Encyclopedia, and other sources, and prepare in your notebook a composition on one or more of the following topics: —

1. The Work of the Board of Health.
2. The Work of the Tenement House Commission.
3. How a City May Be Kept Clean.
4. A Visit to a Model Dairy.
5. City Milk Inspection.
6. A Hygienic House.
7. Helpful Bacteria.
8. City Playgrounds and Parks: Their Use and Abuse.
9. How the Study of Bacteria Can Help Us in Our Homes.
10. Sleeping in the Open Air.
11. A Visit to Ellis Island: How the Commission Cares for Immigrants.
12. The Responsibility of the Individual for Public Health.
13. An Ideal School Infirmary.
14. The Work of the Consumers' League.
15. Methods of Sewage Disposal.
16. The City Water Supply.

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[1] The authors are indebted to Miss Edith Read of the Morris High School for the following list of composition topics.

CHAPTER III

FOODS AND THEIR USES

I. FOOD SUBSTANCES FOUND IN THE HUMAN BODY

42. **Composition of the body.** — Many careful analyses have been made of the composition of the human body, and these analyses have shown that our bodies are made of the same kinds of materials as those found in plants; namely, proteins, fats, carbohydrates, mineral matters, and water.

43. **Proteins.** — The most important substances in the living body are the proteins. As we have already learned,[1] proteins are essential constituents of the protoplasm of every plant cell, and this is likewise true of the cells in animal and human bodies.

44. **Fats and carbohydrates.** — The amount of fat in the body varies greatly in different individuals, but it is always present in some quantity. Muscle, however lean, contains particles of fat; fat constitutes a small percentage of the blood; it fills the spaces in the interior of bones; and it is often deposited in considerable quantity in the deeper layers of the skin. In the blood and in other animal tissues we find some of the carbohydrate called grape sugar. Another carbohydrate known as animal starch, or *glycogen*, is found in the liver and in the muscles.

45. **Mineral matters.** — Mineral matters are found in the greatest quantities in the bones and the teeth. When

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[1] 43, "Plant Biology."

we burn bones, about one third of the weight disappears, the remaining two thirds being bone ash, which is the mineral matter. Every part of the body, however, contains some mineral ingredients; for when muscle, liver, brain, or blood is burned, there remain some traces of ash in each case.

46. **Water.** — The great importance of water in the composition of the human body is evident from the fact that this compound forms about 62 per cent of the weight of an adult. Hence, if all the water were removed from the body of a man weighing one hundred and fifty pounds, the solids that remained would weigh less than sixty pounds. The different organs vary greatly in their percentages of water; bones contain about 22 per cent, muscles have 75 per cent, and the kidneys 82 per cent.

II. The Necessity for Foods

47. **Necessity of foods for growth.** — During the earlier years of life, as we all know, the human body rapidly increases in weight. A child at birth usually weighs seven to eight pounds, whereas the weight of a fully grown man is often one hundred and fifty pounds or more. Hence during a lifetime there is often a twentyfold increase in weight. To provide for this increase or growth a large amount of new material must of course be taken in by the human being, and this material is supplied by the food.

48. **Necessity of foods for repair and for the production of energy.** — On the other hand, it is not difficult to prove that throughout life the body tends constantly to decrease in weight. For instance, if one were weighed on accurate scales immediately after eating and then again after several hours had elapsed and before food or drink had been taken, a decrease in weight would be noted. Still more striking is

the loss of weight due to abstaining from food because of illness or other reasons.

It has been found too that when one is engaged in very active exercise, such as playing tennis or football, the loss of weight is greater than when one remains quiet. How, then, can we account for the loss of weight in all the cases that we have been enumerating? We all know that during violent activity considerable quantities of perspiration are given off from the skin, and this has been proved to be true at all other times, though to a less extent. It has also been demonstrated that many waste materials are given off from the lungs, the organs of digestion, and the kidneys.

We have now accounted for the constant loss of weight in our bodies, but we have still to ask ourselves how these waste substances are produced in the body. The two commonest wastes of the body are carbon dioxid and water. These are produced by the oxidation of the carbon (**P. B., 80**) and the hydrogen in the foods. This has also been proved to be true in animals and in the human body.

49. Definition of a food. — The three most important uses of foods have been suggested in the preceding sections. Hence we may say that a *food is any substance that yields material for the repair or growth of the body, or that supplies the fuel used by the body for producing heat, or power to do work.* It should be understood, however, that no substance should be regarded as a food if it injures the body while supplying materials for growth, repair, or the production of energy.

III. The Composition of Foods

50. To determine the food substances present in milk. — Laboratory demonstration.

1. Shake a bottle containing milk and cream and pour a

small amount into a test tube; add a little strong nitric acid, and boil.

a. Describe what was done.
b. What change in the color of the milk do you observe?
c. What food substance do you therefore conclude to be present in milk?

2. Place a drop of the "mixed milk," used in 1 above, on paper, and allow the paper to dry over a warm radiator. Hold the paper to the light. What kind of food substance is present in considerable quantity in the milk? How do you know?
3. Add a few drops of iodine to some milk. What is the result, and what is your conclusion?
4. Test another sample of milk with Fehling's solution. State the result and your conclusion from the experiment. The sugar found in milk is known as *milk sugar*, and when it is heated with Fehling's solution, it is changed to grape sugar.
5. Heat a half spoonful of milk, and hold over it a clean, dry tumbler. What nutrient does this experiment prove to be present? Why?
6. (Optional.) Evaporate to dryness the spoonful of milk, and then burn the solid residue over a very hot flame. Does all the solid disappear, or is something left on the spoon? What is your conclusion as to the presence or absence of mineral matter in milk?
7. As a conclusion from all your experiments, state what food substances or *nutrients*[1] are present in milk, and what food substances are absent.

51. The composition of other foods. — Our study of milk has shown us that this food is composed of the same

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[1] In our study of plant biology we called the compounds named in this paragraph *food substances* rather than *nutrients*, for botanists regard the simpler compounds (carbon dioxid, water, and mineral matters) that plants obtain from the water and air as the nutrients of the plants. By some writers water is not regarded as a nutrient; since, however, it is an essential constituent of protoplasm, it may well be named among the nutrients.

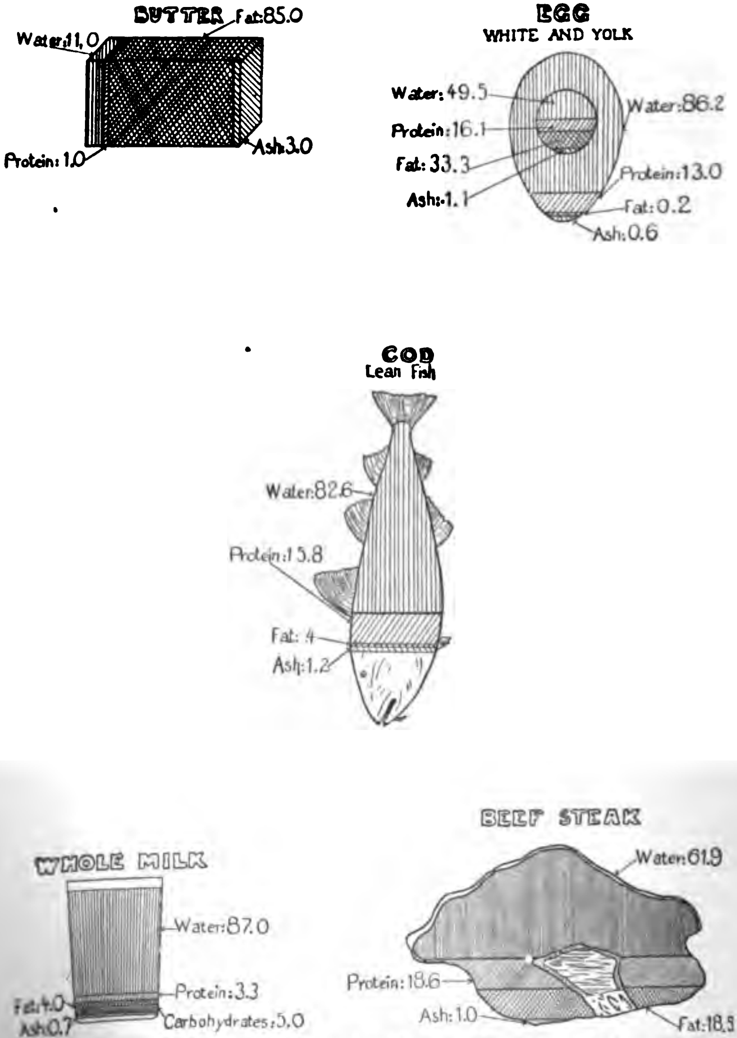

Fig. 19. — Composition of common animal foods. (Drawn from Charts of U. S. Dept. of Agriculture by Mabelle Baker.)

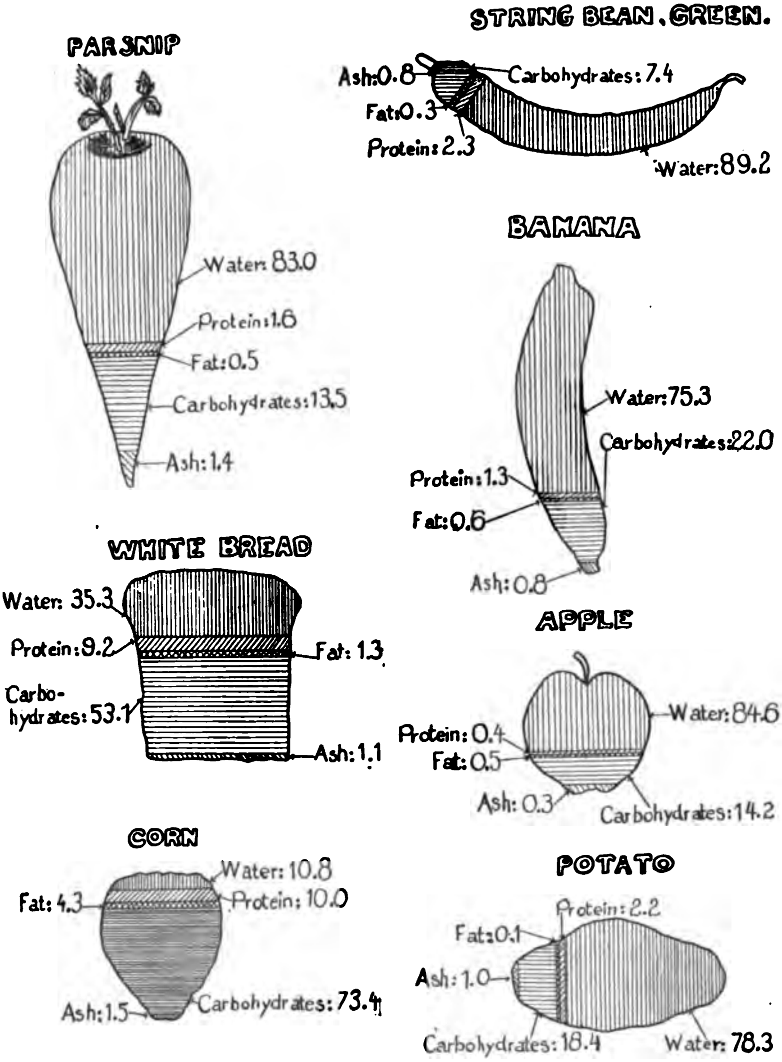

Fig. 20.—Composition of common vegetable foods. (Drawn from Charts of U. S Dept. of Agriculture by Mabelle Baker.)

kind of food substances that we found in plants; and this is what we might expect, since the cow is wholly dependent upon grass and other vegetable foods. Indeed, when we analyze any other animal foods that we eat, we find that all consist of one or more of the food substances which closely resemble those that we have been studying in plant biology. In Figures 19 and 20 are represented not only the various nutrients found in some of our most common foods, but also their relative proportions in percentages.

52. Composition of various foods. — (Home study.)

1. Name the foods represented in Figures 19 and 20 that are derived from animals; name those obtained from plants.
2. Which of the two classes of foods, named in 1 above, has on the average the larger percentage of protein?
3. In which of these two classes do you find the larger amount of fats?
4. Which class has the larger percentage of carbohydrates?
5. What, then, are the principal differences in the composition of animal and vegetable foods?
6. Name the various food substances found in one animal food and in one vegetable food, giving in each case the percentage of each nutrient.

IV. USES OF THE FOOD SUBSTANCES

53. Uses of the food substances to plants and animals. — In our study of green plants we learned that these living organisms can manufacture the food substances they need from the simple compounds (water, carbon dioxid, and mineral matters) found in earth, air, and water, and that these food substances are used for the making of protoplasm and the liberation of energy. Animals and human beings, on the other hand, since they cannot make their foods, are either directly or indirectly dependent on plants for their food supply. They use these food materials, however, for the same purposes as do plants. The use of the individual food substances will now be considered.

54. Uses of proteins. — Protein is an essential constituent of plant protoplasm (**P. B., 43**). This class of nutrients is also essential for the growth and repair of the living substance in muscle, nerve, and all other tissues of the human body. Proteins may also be oxidized in the body and give heat and muscular energy.

55. Uses of fats and carbohydrates. — The chief fuel ingredients of food, however, are the fats and carbohydrates. Most of the fat in our foods is probably oxidized soon after it reaches the cells to furnish heat and power, and this class of nutrients possesses two and a half times the fuel value of any other kind of food substance. This is the reason why the inhabitants of arctic countries eat such large quantities of fatty foods.

The starches and sugars of bread, potato, fruits, and milk are also used as fuel. The fat which we stated (**44**) is stored in various parts of the body, is derived partly from the carbohydrates and partly from the fats in our food, and this acts as a reserve fuel. That portion of the fat which is stored in the deeper layers of the skin helps to keep our bodies warm by preventing the escape of heat.

56. Comparison of uses of the nutrients. — It is evident that the three nutrients thus far studied may be used to supply the body with energy. If our diet is deficient in any one of the three, the others supply the need, and are burned instead. For growth and repair, however, proteins are absolutely essential; neither carbohydrates nor fat can be transformed into this essential ingredient of protoplasm. Hence, an animal soon dies if it is not supplied with proteins.

If a machine is to do a large amount of work, it must be large enough and strong enough, and must have plenty of fuel. This is true of the body machine. A man who does hard work, and a good deal of it, needs plenty of proteins in his food to build up his tissues and keep them in repair, and plenty of fats and carbohydrates for fuel.

57. Uses of mineral matters and water. — The mineral matters like phosphate and carbonate of calcium and magnesium are necessary for making bones and teeth, and for the making of protoplasm (P. B., 43). Salt is used in large quantities by all civilized nations; it makes food more palatable and it is important in the making of digestive fluids.

Water is an essential constituent of protoplasm, and hence the body needs it constantly. Water also aids in dissolving foods. A considerable amount is supplied by the water contained in some of our solid foods, and we get the rest from the water and other beverages that we drink.

V. COOKING OF FOODS

58. Importance of proper cooking. — Some of our foods, like milk, nuts, and fruits, are eaten without being cooked. The great majority, however, before they are taken into our bodies are changed considerably. It is important for us to learn the essential principles of good cooking, since food, as often prepared, loses much of its flavor, becomes more or less indigestible, and is deprived of a considerable percentage of its nutrition.

59. Reasons for cooking animal foods. — In civilized communities meats and other animal foods are usually cooked by broiling, roasting, boiling, or frying. The reasons for cooking the flesh of animals are these: (1) proper cooking loosens and softens the fibers, thus preparing the meat for mastication and for the action of the digestive juices; (2) the heat kills the harmful bacteria and other parasites (*e.g.* tapeworms) that are sometimes found in foods of animal origin; (3) cooking makes the meat more attractive in appearance and often improves its flavor; and (4) cooked meat is more *completely* digested. It is probably true, however, that raw or partly cooked meats are more *easily* digested.

60. Frying. — If meats are fried, the skillet should be very hot, so that the surface of the meat may be coagulated at once, thus preventing the escape of nutrients and the entrance of fats. Frying usually involves the use of additional fats, and since frying tends to make foods indigestible, this is doubtless the poorest method of cooking meat.

61. Soups. — If we wish to obtain nutritious soups, the meat should be cut into rather small pieces and first put into cold water to which a little salt has been added. A small proportion of the proteins, and large amounts of so-called "extractives," or flavoring matters, are drawn out by the water and salt, and since the meat is in small pieces, a considerable proportion of the mineral matter is thus dissolved. When we warm the mixture, we cause the fats to melt, and when it is boiled, much of the tough connective tissue is made more or less soluble by being turned into gelatin. The soups thus obtained are made more palatable by the addition of condiments.

The meat which is left after the soup has been prepared is more or less tasteless. Only small percentages, however, of the nutrients have been withdrawn; hence the soup meat should not be thrown away, but should be used as described in **71**.

62. Stewing. — It is unfortunate that stews are not more highly regarded in American families, for by this method of preparing animal foods all the nutritive ingredients are utilized. To make a good stew the meat should be cut into rather small pieces and placed in cold water. Some of the flavoring matters and soluble proteins pass out into the broth, making it rich and nutritious. When the stew is allowed to simmer for several hours on the back of the stove, the meat itself becomes tender and readily digestible. The addition of vegetables makes it a most nourishing and palatable dish.

63. Boiling meats. — When the meat itself is to be eaten, and the broth is not to be used, the whole piece should be plunged into boiling water for a few moments. In this way the protein on the surface is quickly coagulated, and the crust thus formed prevents the loss of the meat juices. The temperature of the water should then be reduced somewhat below the boiling point by pushing the kettle toward the back of the stove, and the meat should then cook slowly until it is done. A piece of meat, when cooked in this way, is tender and juicy throughout. If, however, the water is kept at the boiling point (212° F.), the meat may be easily torn apart, but the fibers are found to be hard and stringy.

64. Roasting and broiling. — The best method of cooking the flesh of animals, if the broth is not desired, is by roasting or by broiling, since smaller percentages of the nutrients are lost than is the case in boiling. The outer layer of protein must, however, be coagulated at once, and for this purpose a very hot fire is needed.

When the piece to be roasted is small, the high temperature should be maintained until the meat is cooked. A large roast, on the other hand, after the outer covering has been coagulated, requires a slower fire and a longer time; meat is not a good conductor of heat, and a hot oven would scorch the outside before the central mass could become thoroughly cooked. A better crust is formed on the outer surface of the roast if the meat juices in the pan (mostly fat) are frequently poured over the surface of the roast. This is called "basting."

65. Reasons for cooking vegetables. — The starches, which are present in large quantity in foods of vegetable origin, are usually inclosed in cells, the walls of which are formed of indigestible cellulose. Hence, before starch can be digested, it must be freed from this cellulose envelope. This is largely accomplished by cooking, which causes the starch grains to swell. The cell walls are broken open in this way, and when the grains burst, a larger surface is exposed to the action of the digestive juices (Figure 21). This is strikingly shown in popping corn. The crust of bread is more easily digested than the softer parts, and toasting bread increases its digestibility, because this browned starch (sometimes called soluble starch) requires less change before it can be used by the body.

66. Boiling vegetables. — Experiments have shown that a good deal of nutriment is lost by boiling vegetables in water. Much of this waste may be avoided, however, if one heeds the following directions: (1) vegetables should be cooked as far as possible in their peels, for these outside coverings keep the sugar, proteins, and mineral matters from being drawn out by the water; (2) if the vegetables must be peeled and cut up, the pieces should be relatively large, as a smaller surface is thus exposed to the water; (3) the amount of water should be as small as possible, and the vegetables should be cooked rapidly, in order to give less time for the solvent action to take place.

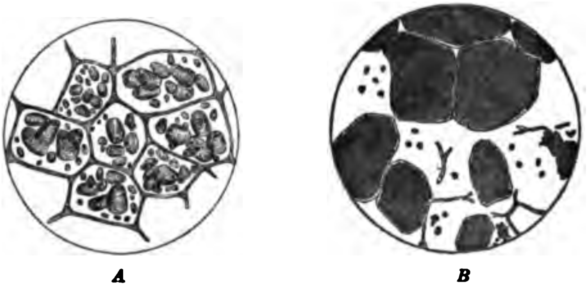

FIG. 21. — *A*, cells of raw potato with starch grains inclosed in the cellulose walls. *B*, cells of a potato well steamed and mashed; starch grains have been burst by the heat.

67. Bread making. — When bread is made, water (or milk), butter, salt, sugar, and yeast are added to flour. After the mixture has been stirred together, a sticky mass of dough is formed, which, in a warm place, begins to rise. This is due to the fact that the yeast cells change the sugar into alcohol and carbon dioxid. Bubbles of gas are thus imprisoned in the sticky dough. While expanding and seeking to escape, the gas makes the solid mass porous. After the bread has risen sufficiently, it is kneaded in order to break up the large bubbles and in order to distribute the gas throughout the dough. When the bread is baked, the alcohol and carbon dioxid pass off into the air, leaving the bread light and digestible.

VI. Food Economy

68. Importance of food economy. — It is said that in a large proportion of American families more than half the total income is spent for food, and that the remainder of the income must serve for rent, fuel, clothing, doctor's bills, and other expenses. Hence, any saving that can be made in the annual food bill of a family should result in a surplus which may well serve as a nucleus of a saving's bank account, or may be used in improving the home surroundings or in securing wider means of education and enjoyment. The average American, however, is far from economical in the matter of foods. In the first place there is often extravagance in the purchase of food, and in the second place foods are frequently wasted in the home.

69. Comparative cost of foods. — (Home study.) The chart shown in Figure 22 exhibits (1) the cost price of each of the foods represented, (2) the weight of the food that may be purchased for 25 cents, and (3) the weight of the solid food substances (except mineral matters) that may be purchased in each food for 25 cents. Note at the top of the chart the short vertical lines that indicate 1 pound, 2 pounds, etc., of solid nutrients; hence, if 25 cents is spent for wheat flour, about ¾ of a pound of protein can be secured, ¼ of a pound of fat, and about 6½ pounds of carbohydrates.

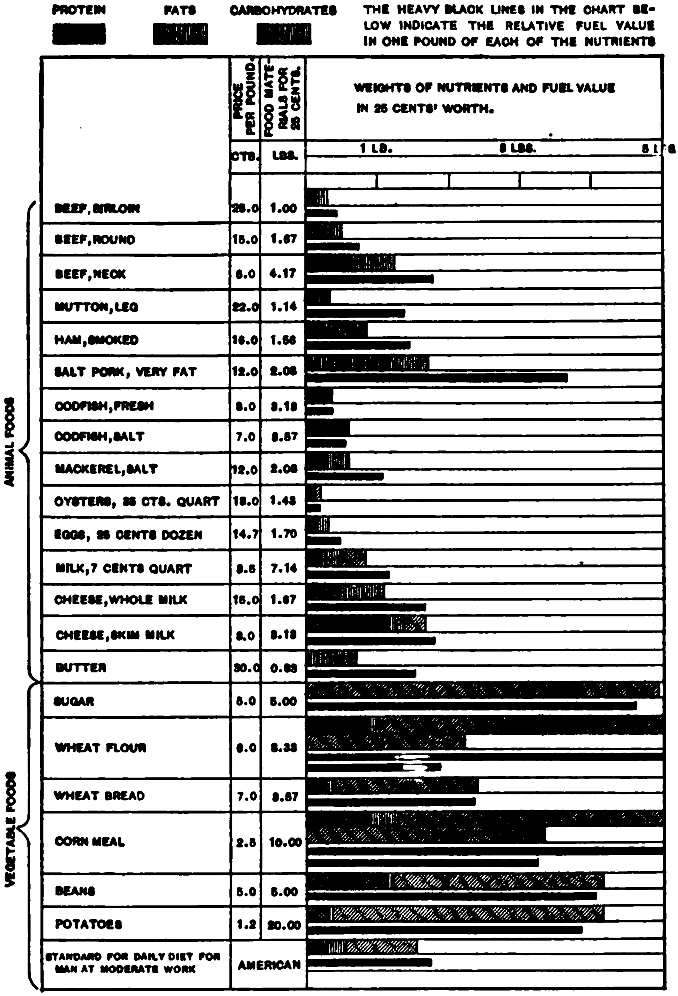

FIG. 22. — Economy in the purchase of foods. Prices in this chart were those in the year 1900. Compare with prices to-day. (U. S. Department of Agriculture.)

1. Name the foods represented in Figure 22 that are derived from animals; name those obtained from plants.
2. On the average, can larger amounts of the animal or of the vegetable foods represented on the chart be purchased for 25 cents?
3. Bearing in mind the relative work and expense in producing animal and vegetable foods suggest some explanations for the answer you have given to question 2.
4. Which one of the foods on the chart would you buy if you wished to get the largest amount of solid nutrition for 25 cents; that is, which food is the most economical?
5. From which kind of food would you get the smallest amount of solid nutrients? Name other foods on the chart which are more expensive per pound than the one that you have just named.
6. Which of the three kinds of beef named on the chart would be the most economical for soup or stew?
7. Name three classes of food substances needed in the diet of the average American engaged in moderate work (see last line on the chart), and estimate the weight of each that is needed during a day.
8. Which food on the chart comes the nearest to supplying in the right proportions all the nutrients named in 7? In the food you have named which kind of food substance is not present in sufficient proportion?
9. Why is it better to eat a variety of foods rather than any one kind?
10. Suggest a reason why meat and potato should be eaten together; bread and butter.

70. Economy in the purchase of foods. — The animal foods, we have just learned, are considerably more expensive than the staple foods of vegetable origin. Hence, in an economical household the proteins needed by the body should be largely obtained from vegetable foods like bread, corn meal, and beans. If this plan were followed, a considerable saving in the year's expenses might be effected. Figure 22 shows the weights of different food materials that may be purchased for 25 cents. On comparing the two meats at the top of the chart, one can see that a greater fraction of a pound of solid nutriment may be obtained by spending 25 cents for round steak than could be secured by the purchase of sirloin. Yet the latter is bought even in very poor families. From oysters one gets less of the solid nutrients than from any other food represented on the chart; therefore, if one's income is small, this kind of food should be regarded as a luxury, seldom purchased except in case of sickness.

71. Economy in the use of foods. — In discussing the cooking of foods, we suggested some of the ways by which the loss of nutritive ingredients may be prevented. We waste foods, however, in other ways; for instance, we often throw away bones and gristle, regardless of the fact that they contain a considerable percentage of protein, gelatin, and fat from which one might make a nutritious soup. It has been found that large proportions of the food materials still remain in a piece of meat after it has been used for soup, even though it is more or less tasteless. This meat should not be thrown away, however, but should be chopped up and combined with vegetables and condiments to make a hash. The garbage pails of most kitchens receive far too large a percentage of the food that is bought for the household, and many a dollar could be saved for other purposes if more care were exercised to prevent this waste.

The food problem, then, for the healthy human being is this — *how to obtain the largest amount of good, nutritious food for the least money.* To this problem an intelligent housekeeper, if she can be led to see the importance of the subject, will devote considerable thought. This problem cannot be solved, as we have seen, by consulting market prices only, for often the highest-priced foods contain small percentages of the nutrients. Neither can we be sure of a good supply of foods by following our tastes. To many people cakes and sweetmeats are more appetizing than sandwiches and cereals. Yet it is the latter that usually supply the available proteins, at a lower cost.

The composition of various foods can be found only by chemical analysis, and their nutritive value can be determined only by experiment. Fortunately these analyses and experiments are being carried on by the United States government. The results are published in the Bulletins[1] of the Department of Agriculture, Washington, D.C., many of which will be sent free to any address.

VII. DAILY DIET

72. Amount of each nutrient required. — Many investigations have been carried on, in this country and in Europe, to determine the amount of each kind of nutrient needed per day for the work of the body. The conclusions that were drawn from this study are represented on the last line of Fig. 22. According to these conclusions the average American, when doing moderate work, requires about one fourth of a pound of proteins to provide for the growth and repair of the body, and a quarter of a pound of fat and a pound of carbohydrates to furnish the needed energy.[2] This is about the amount eaten by a man of average appetite. In order to secure a heathful diet, the general principles stated in the following paragraphs should be borne in mind, by an adult or by a growing boy or girl.

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[1] The most suggestive of these publications are "Foods, and the Principles of Nutrition," "Meats: Composition and Cooking"; "Milk as a Food"; "Fish as a Food"; "Sugar as a Food."

[2] Recently, however, at the Scientific School of Yale University, some very careful experiments have been performed by Professor Chittenden which seem to prove that this quarter of a pound of pro-

73. Necessity for a mixed diet. — A sufficient variety of foods should be eaten at each meal to obtain all the nutrients needed. In 69 we learned that in none of the foods on the chart are the nutrients in the right proportions. Cow's milk comes the nearest to being a perfect food, but its percentage of carbohydrates is too small. If we were to feed on meat alone, we should get too large an amount of proteins; while most of the vegetable foods are lacking in fats. Hence, a well-balanced diet should consist of a mixture of many kinds of foods. Such a diet will supply not only the proteins, fats, and carbohydrates, but also the mineral matters so necessary in the development of the bones and teeth, and in the making of living substance. In fact, some foods, such as spinach, are valuable chiefly on account of the mineral matters which they contain. If the appetite is normal, one is fairly sure to secure the nutrients in approximately the right proportions.[1]

tein for each day is considerably more than the body really needs. Dr. Chittenden experimented on five of the Yale University professors, on thirteen soldiers of the United States army, and on five of the best athletes at Yale; he found that all agreed that they could do better physical and mental work, and do it without any loss of weight, when they had become accustomed to taking less than half their ordinary amount of proteins. In several instances rheumatism, biliousness, and other derangements of the body were cured by this restricted diet. "There is no question, in view of our results," says Professor Chittenden, "that people ordinarily consume much more protein food than there is any real physiological necessity for, and it is more than probable that this excess of food is in the long run detrimental to health, weakening rather than strengthening the body, and defeating the very objects aimed at."

[1] It is desirable that pupils prepare a list of the kinds of foods and beverages, stating quantity of each, that formed their diet on the

74. Avoidance of indigestible foods. — Frequently individuals find that they cannot eat certain kinds of foods, *e.g.* cheese, honey, cucumbers, without discomfort. Hence, in selecting their diet these foods should not, of course, be eaten. Foods that are hard to digest, such as fried foods, heavy bread, or pastry, should be avoided, especially by growing girls and boys.

75. Sugars as a part of the diet. — Carbohydrates, we have found, are essential constituents of our foods. If, however, sugars are eaten between meals, too much of this kind of food substance is likely to be consumed, the appetite for other foods is lessened, and digestive disturbances are likely to follow. Consequently the pastry and confectionery that are eaten should form a part of dessert.

76. Review of Foods

NAME OF NUTRIENT	TEST FOR NUTRIENT	USES OF NUTRIENT	FOODS CONTAINING NUTRIENT
Protein (albumin, nitrogenous food).	Coagulates when heated. Turned to yellow color by nitric acid.	Necessary for the manufacture of protoplasm. When oxidized releases energy.	Meat, eggs, milk, cheese (among animal foods), and beans, peas, oatmeal (among vegetable foods).

three meals of some stated day. These menus should then be read and discussed by teacher and pupils, and such suggestions for improvement should be made as may seem necessary.

NAME OF NUTRIENT	TEST FOR NUTRIENT	USES OF NUTRIENT	FOODS CONTAINING NUTRIENT
Starch.	Turned to a blue color by iodine solution.	Changed to sugar, source of energy, and may be transformed into body fat.	Vegetable foods (especially cereals).
Sugar.	Fehling's solution is turned orange or red when boiled with grape sugar.	Source of energy. Transformed into body fat.	Vegetable foods (especially fruits); milk sugar is found in milk.
Fats (or oils).	Make translucent spots on paper. Dissolved by ether or benzine.	Source of energy. Transformed into body fat.	Animal foods (especially butter, pork, cheese), vegetable foods, as nuts, cocoa, chocolate.
Mineral matters.	Left as ash after food is burned.	Help to form bone, teeth, and other tissues. Aid in digestion.	Common salt; mineral matters in most vegetable and animal foods.

CHAPTER IV

STIMULANTS AND NARCOTICS

I. DEFINITIONS

77. Stimulants. — In the preceding chapter we discussed food substances, and these, we learned, yield material for the repair or growth of the body, or supply the fuel necessary for producing energy in the body. But in addition to the various nutrients that may be used for one or all of these purposes, we often take with our food certain substances that are not useful to any considerable extent in any of these ways. As examples of such substances, we may mention spices. Such substances add an agreeable flavor to our foods, and so stimulate our appetites; hence, they are known as *stimulants*. *A stimulant is any agent that temporarily quickens some process in the body.* The most common stimulants are tea, coffee, and alcohol.

78. Narcotics. — Another class of substances that we sometimes use has an effect directly opposite to that of stimulants. Ether, morphine, and chloroform, for example, do not quicken any process in the body as do stimulants, but, on the contrary, lessen the degree of activity. Any compound that acts in this way is called a *narcotic*. *A narcotic is any substance that directly induces sleep, blunts the senses, and in sufficient amounts produces complete insensibility.*

II. Beverages

79. General effect of tea and coffee on the body. — The effect of tea and coffee on the body is due to the presence of essentially the same *stimulant* in both (caffein), which acts largely on the nervous system. In both tea and coffee, as they are usually prepared, is another substance known as *tannin.* This chemical, when obtained from the bark of certain trees, is used in tanning or hardening leather. When tannin is taken into the stomach, it is found to injure the mucous membrane and to retard digestion.

80. The preparation of tea and coffee. — To prepare tea properly, boiling water should be poured upon tea leaves, and the infusion allowed to stand only a few minutes before pouring. Tea should never be put on the stove to boil, for two reasons: in the first place, by this treatment the delicate taste and odor of the beverage are lost; and in the second place, if the tea infusion is boiled, a considerable quantity of the tannin is dissolved by the water. Obviously the tea grounds should not be used a second time.

Most that has been said in regard to tea applies equally well to coffee, except that in the preparation of coffee the infusion should be put on the stove and allowed to come to a boil; it should then be poured out, and should not stand on the coffee grounds; otherwise the tannin will be extracted. Coffee is best prepared by the use of a percolator, since in this utensil the water is continuously forced over the ground coffee.

81. The use and abuse of tea and coffee. — "When properly made, tea in moderation is a wholesome, agreeable, and refreshing stimulant beverage, particularly grateful in conditions of mental or physical weariness. Used in excess, it exerts a harmful influence upon the nervous system, and in a too strong form injures the digestive organs." The foregoing remarks, quoted from Harrington's "Practical Hygiene," apply to adults rather than to growing children and youths; for in early life stimulants of every kind should be avoided as much as possible, as they tend to interfere with the healthful development of the body. We should remember that tea and coffee are not foods, and so cannot be of use in repair or growth of tissue, both of which functions are of prime importance during the first twenty years of life. The habitual use of these beverages, especially at breakfast, is also likely to decrease the desire for the food that is needed.

82. Chocolate, cocoa, and soda water. — While it is true that cocoa and chocolate both contain a considerable amount of nutriment when eaten in solid form, when prepared as a beverage, the small amount so used makes its food value relatively unimportant unless milk is used. Chocolate and cocoa contain a certain amount of a stimulant similar to that found in tea and coffee. Since the sirups and ice cream used in the preparation of soda water contain a considerable amount of sugar, these drinks should not be taken habitually between meals, because they tend to impair digestion and to lessen the appetite at meal time (75).

83. Alcoholic beverages. — "In the case of an alcoholic beverage we have to deal with something which, like tea and coffee and cocoa and 'temperance drinks' is used as a beverage, and to that extent must be classed in the same group. Alcoholic drinks are, however, taken as stimulants, and so resemble tea and coffee and cocoa; but they differ from all these in their action upon the body. Moreover, their abuse gives rise not only to degraded moral and social conditions, but is also attended with bad hygienic effects. Every one should be informed of their nature and of the dangers attending their use." — HOUGH and SEDGWICK, "The Human Mechanism."

84. Alcohol as a possible food. — Like the carbohydrates and fat, alcohol is composed of carbon, hydrogen, and oxygen. Since it contains no nitrogen, it has no value in the processes of growth and repair; in other words, it cannot be made into protoplasm. It cannot, therefore, like meat, milk, and eggs answer as a complete food.

Alcohol we know may be burned in lamps for the production of heat, and in engines for the generation of power. Professor Atwater has shown that alcohol also, if used in sufficiently small amounts, may produce within the human body a certain amount of heat and muscular power. Indeed, in some cases of extreme weakness, especially in diseases, alcohol is regarded by some eminent physicians as necessary for saving life, though even for this purpose it is now being used to a less extent in medical practice.

85. Alcohol as a stimulant and a narcotic. — On account of the amount imbibed, however, alcohol, as ordinarily used in beverages, is practically always either a stimulant or a narcotic. In later sections we shall discuss the effects of alcohol on various organs of the body. One fact should, however, be continually emphasized; namely, that even if it should be taken for granted that alcohol, when used by *adults in moderation*, may generate a certain amount of energy, still *this is an exceedingly dangerous compound* to introduce in any form into the diet of a boy or girl. In the first place, it interferes with the healthy growth of protoplasm; and in the second place, the use of liquors in moderation by a great many people, both young and old, is absolutely impossible. Men never become drunkards, paupers, and criminals by taking the nutrients, starch, sugar, fat, or protein, nor does the taste for any one kind of food become uncontrollable, as is so often the case with alcohol. "Till he has tried it, no one can be sure whether he can control his appetite or not. When he has ascertained the fact, it is often too late. The child should be taught to avoid alcohol because it is dangerous to him. The only certain safety for the young lies in total abstinence."

86. Effects of small and large quantities of alcohol. — The effects of alcohol on the body depend very largely upon the quantity taken; if the amount is small, alcohol may possibly be regarded as a source of energy, and hence in a limited sense, as a food; in larger amounts it increases temporarily the activity of the organs of the body, and so it seems to become a stimulant; if still larger quantities are taken, the narcotic effects of alcohol are shown in complete insensibility; and finally, a sufficient amount may be consumed to poison the organs and cause death. No one who begins the use of alcohol expects to take such an amount that it will act as a poison, or even like a narcotic. There is, however, a constant danger that he will do so.

87. Professor Hodge's experiments with dogs. — During the years 1895 to 1900, Professor Hodge of Clark University, Worcester, Mass., carried on some very instructive experiments upon dogs. He secured four spaniel puppies (Fig. 23), all of which were born on Washington's Birthday, 1895; the two males were brothers, and the females sisters. Professor Hodge carefully watched the four for nearly two months before beginning his experiments, in order to pick out the two most vigorous animals; these he named "Tipsy" and "Bum," and then put in with their chief meal each day a moderate amount of alcohol; it was not enough, however, to cause any evidence of intoxication. The other two spaniels, "Nig" and "Topsy," received no alcohol.

88. Effect of a moderate amount of alcohol on activity. — For over five years these dogs were studied, and important facts were learned as to the general effect of alcohol on physiological processes. Early in his observations it became evident to Professor Hodge that the dogs that were receiving the alcohol were far less playful than were those that had no alcohol in their food. To measure the comparative activity of the different animals, he attached to the collar of each dog a Waterbury watch adjusted in such a way that it would tick

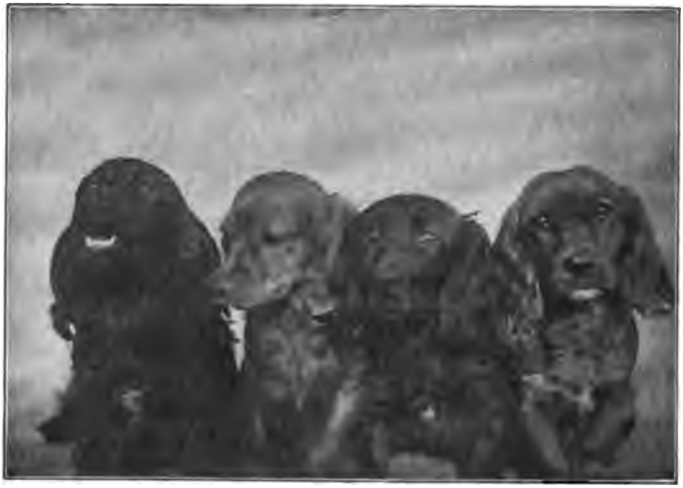

FIG. 23. — The appearance of the four spaniels six months after the experiments were begun. ("Physiological Aspects of the Liquor Problem," by permission of Dr. Hodge and of Houghton, Mifflin & Co.)

once each time the animal moved, and so at the close of each day he could determine and set down the record made by each dog. He found that for a period of two months and more " Bum " was only 71 per cent as active as " Nig," while " Tipsy " was only 57 per cent as active as "Topsy" ; in other words, the two alcoholic dogs lost 25 per cent to 50 per cent of their activity.

89. Effect of a moderate amount of alcohol on skill and endurance. — A second series of experiments was made to determine the comparative endurance of the four dogs and their ability to accomplish things. The animals were all taught to retrieve a rubber ball when it was thrown the length of the gymnasium floor, a distance of 100 feet. At each trial the ball was thrown 100 times, and a record was kept of all the dogs that started for the ball and of the one that succeeded in bringing it back. When he had averaged a long series of experiments, Dr. Hodge found that " Bum " and " Tipsy " secured the ball only about half as often as did " Nig " and "Topsy " ; the two alcoholic dogs also gave evidence of much greater fatigue during the trials.

90. Effect of a moderate amount of alcohol in producing nervousness. — " A very striking result of the entire research," says Dr. Hodge, " and one entirely unexpected on account of the small doses of alcohol given, has been the extreme timidity of the alcoholic dogs. . . . While able to hold their own with the other dogs in the kennel, the least thing out of the ordinary caused practically all the alcoholic dogs to exhibit fear, while the others evinced only curiosity or interest. Whistles and bells, in the distance, never ceased to throw them into a panic in which they howled and yelped, while the normal dogs simply barked. This holds true of all the dogs that had alcohol in any amount."

91. Effect of a moderate amount of alcohol on the offspring. — Another most striking result of the use of alcohol was shown in its effects on the young of " Bum " and " Tipsy." Of the twenty-three puppies descended from these alcoholic animals, only 17 per cent lived to be normal dogs; the rest were either deformed or unable to nourish themselves, and all died soon after birth. On the other hand, of the forty-five young of " Nig " and " Topsy," over 90 per cent were healthy puppies. Hence, the puppies of the dogs that took alcohol even in moderation were over *five times* as likely to die young as were the puppies born of abstaining parents.

92. Effect of a moderate amount of alcohol on resistance to disease. — In the spring of 1897, in the course of these experiments, a great many dogs throughout the city of Worcester were afflicted with distemper, and dogs sick with the disease were not uncommon on the streets. At that time, Dr. Hodge had, in all, five dogs that were taking alcohol and four that were not. It was found that there was a marked difference in the effect of the disease on the two classes of animals. All the alcoholic dogs, with the exception of the one that had taken the smallest amount, had the distemper with great severity; all the normal dogs had it in the mildest possible form.

93. Summary of Professor Hodge's conclusions. — Hence, we may conclude from these experiments that alcohol, when given to dogs, even in moderation, (1) decreases their natural activity, (2) lessens their power of endurance and their ability to accomplish things, (3) decreases their power of resistance to disease, and (4) increases the percentage of deformity and of death among their offspring. These conclusions have a most important bearing on the general subject that we are considering, for observations show that similar effects follow even the moderate use of liquor by human beings, as the following paragraphs will show.

94. Effect of the moderate use of alcohol on mental activity. — " Few causes are more effective in leading to the abuse of alcohol than the idea that when one finds difficulty in doing a thing it may be accomplished more easily by having recourse to beer, or wine, or whisky for their ' stimulating ' effect. In general, so far is this from being the truth that the person seeking such aid is really using a hypnotic and a depressant. Obviously he would be acting more wisely to adopt other methods of accomplishing his end. Nor is this conclusion merely theoretical. Brain workers who wish to " keep a clear head " almost universally avoid alcoholic drinks, at least until work is over. And even among those who do drink it is customary to avoid drinking until the day's work is done." [1]

95. Effect of a moderate use of alcohol on muscular activity. — That the general effect of alcoholic drinks on muscular activity is a depressant rather than a stimulant was shown by experiments on English soldiers during forced marches in Africa. " It was found that when a ration of rum was served out, the soldier at first marched more briskly, but after about three miles had been traversed the effect of it seemed to be worn off, and then he lagged more than before. If a second ration were given, its effect was less marked, and wore off sooner than that of the first. A ration of beef tea, however, seemed to have as great a stimulating effect as one of rum, and not to be followed by any secondary depression." — T. Lauder-Brunton.

96. Effect of a moderate use of alcohol on manual dexterity. — A German scientist determined the effect of alcohol on four typesetters in the following way. "Four days were used for the tests, the first and third of which were 'normal' days; the second and fourth were 'alcohol days.' On the alcohol days each man received about seven ounces of a Greek wine . . . a quarter of an hour before the trials took place." On the "alcohol days" it was found that the amount of type set was on the average 15 per cent less than that set on the "normal days."

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[1] Hough and Sedgwick, "The Human Mechanism."

97. Moderate use of alcohol in relation to disease. — "A much larger number of the victims of alcoholic intemperance die of some infectious disease than of the special alcoholic infections. Attention has been repeatedly called in this article to the lowering of the resistance of alcoholic patients to many infectious diseases. . . . This lowered resistance is manifested both by increased liability to contract the disease and by the greater severity of the disease." — DR. WELCH, in "Physiological Aspects of the Liquor Problem." Physicians also recognize that those who use alcohol are more susceptible to pneumonia, cholera, and other diseases, and that the percentage of recovery of such patients is lower than is that of total abstainers.

98. Total abstinence and life insurance.[1] — "It is now becoming generally recognized that the alcohol habit is one of the main factors in determining length of life. No life office will knowingly accept the proposal of any one known as a hard drinker. Evidence of a very striking kind is rapidly accumulating, which shows that even the moderate use of alcohol is prejudicial to health and longevity. In England about a dozen life offices recognize this fact in one of two ways: (1) by giving a reduction of premium to abstainers, or (2) by awarding them a larger share in the profits.

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[1] These quotations were furnished the authors by the Equitable Life Assurance Society of the United States.

"Ten years ago the American Temperance Life Insurance Association was formed in this city (N. Y.), and accepts nothing but total abstinence risks. It has had pronounced success, and has paid something like $200,000 in death claims. President Frank Delano states that *the results of their business show that the ratio of their death rate to that of general risks is about* 26 *per cent in favor of the total abstainer.*" — William E. Johnson.

99. Business arguments for total abstinence. — The value of total abstinence as a business asset is clearly shown by the following rules of railroads: Rule 17, New York Central & Hudson River R.R.: "The use of intoxicating drink on the road or about the premises of the corporation is strictly forbidden. No one will be employed, or continued in employment, who is known to be in the habit of drinking intoxicating liquor."

Rule H, New York, New Haven & Hartford R.R.: "The use of intoxicants by employees while on duty is prohibited. Their habitual use, or the frequenting of places where they are sold, is sufficient cause for dismissal."

General Order No. 12, Delaware, Lackawanna & Western R.R.: "The use of intoxicants while on or off duty, or the visiting of saloons or, places where liquor is sold, incapacitates men for railroad service, and is absolutely prohibited. Any violation of this rule by employees in engine, train, yard, or station service will be sufficient cause for dismissal."

100. The cost of intemperance. — The following figures, compiled by the League for Social Service of New York City from the United States Census, present some very striking facts as to the cost to our country of the abuse of alcohol. During the year 1880 (and the same figures would doubtless hold true for any other year), it was found that *three fourths* of all the pauperism, *one fourth* of all the insanity, and *three fourths* of all the crime in the United States were directly caused by intoxicating drinks. Hence if the use of intoxicating liquor could be abolished, the heavy expense of maintaining the police force, the criminal courts, insane asylums, and charity organizations, would be very greatly reduced.

101. Concluding remarks on the use of alcoholic beverages. — "In the foregoing pages we have stated the salient facts concerning the physiological action of alcohol and alcoholic drinks. It only remains to point out for the student the obvious conclusions to be drawn from them and from the long and on the whole very sad experience of the race with alcoholic drinks. The first is that, except in sickness and under the advice of a physician, alcoholic drinks are wholly unnecessary, and much more likely to prove harmful than beneficial. The last is that their frequent, and especially their constant, use is attended with the gravest danger to the user, no matter how strong or self-controlled he may be. . . . The only absolutely safe attitude toward alcoholic drinks is that of total abstinence from their use as beverages." — HOUGH and SEDGWICK, "The Human Mechanism."

III. TOBACCO

102. Effect of tobacco on growth. — In discussing the effects of tobacco, it is important, as was the case with tea and coffee, to distinguish between the results of its use by the young and by adults. Just because his father seems to be using tobacco without harm is no reason why a boy can safely smoke. We have already called attention to the complex composition of protoplasm. During the whole period in which the body is attaining its growth this living substance is affected far more appreciably and seriously by the use of stimulants and narcotics than is the case later in life.

Tobacco is a narcotic in its effects; that is, it tends to decrease activity and likewise growth. That such is its effect during early life has been abundantly proved in many ways. But perhaps the most conclusive facts are those presented by actual measurements made in college gymnasiums. Dr. Hitchcock, of Amherst College, who has made careful measurements of college students for a good many years, finds that those who do not smoke increase in height during their college course 37 per cent more than those who do smoke, and in chest girth this difference is 42 per cent, or nearly one half as much again. Dr. Seaver of the Yale Gymnasium finds, also, that in height and lung capacity smokers are considerably inferior to those who do not use tobacco.

103. Effect of tobacco on mental development. — Dr. George L. Meylan, Director of the gymnasium of Columbia University, made a careful comparison during two years of the relative physical measurements, rate of growth, and scholarship of 115 college men who smoked and 108 men in the same class who were non-smokers.[1] He found (1) that the smokers were on the average eight months older, which means that they had entered college this much later; and (2) that "the scholarship standing of smokers was distinctly lower than that of the non-smokers," showing "that the use of tobacco by college students is closely associated with idleness, lack of ambition, lack of application, and low scholarship."

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[1] *Popular Science Monthly*, August, 1910.

"Whatever difference of opinion there may be regarding the effect of tobacco on adults — and much difference of opinion exists — there is almost complete agreement among those best qualified to know that the use of tobacco is in a high degree harmful to children and youths. Physicians, teachers, and others who have much to do with boys very generally remark that those who begin to smoke at an early age very seldom amount to much."

Dr. Andrew D. White, for twenty years President of Cornell University, out of his wide experience in education, sums up the matter as follows: "I never knew a student to smoke cigarettes who did not disappoint expectations, or to use a vernacular expression, 'kinder peter out.' I consider a student in college who smokes as actually handicapping himself for his whole future career. I am not fanatical in regard to smoking. It seems to me possible that men who have attained their growth and are in full health and strength may not be injured by moderate smoking at times. I will confess to you that at one period of my life I was a smoker myself, though in a very moderate degree. And should you feel a strong desire to smoke, thinking it may rest you and change happily at times the current of your thought, I may perhaps commend to you my own example; for I began my smoking at the age of forty-five and ended it ten years ago at the age of seventy."

104. Tobacco and athletics. — One of the rules rigidly enforced in athletic contests is that all candidates must abstain from the use of tobacco while in training. The reason for this insistence is the fact that tobacco seriously interferes with the action of the lungs and heart; therefore, those who smoke are found to be easily "winded" in the games.

An investigation[1] has been recently carried on among the football squads of fourteen of the American colleges and universities to determine the relative success of the smokers and non-smokers who tried for positions on the varsity teams.

"Six institutions furnished data relating to the 'try outs.' A total of 210 men contested for positions on the first teams; of this number 93 were smokers, and 117 were non-smokers. Of those who were successful, 31 (*i.e.* 33 %) were smokers, and 77 (*i.e.* 65 %) were non-smokers. It will be observed that only half as many smokers were successful as non-smokers. . . ."

Hence, the ambitious boy, who has any regard for developing a vigorous body fitted for athletic success, for training a mind capable of clear thinking, and for preparing himself for a successful life work, will resist all temptations to smoke, at least until he has attained his full growth.

IV. DRUGS AND PATENT MEDICINES

105. Headache powders. — Drugs are chemical substances used in the preparation of medicines. They should never be taken except under the direction of a competent physician. Headache medicines usually contain some chemical (*e.g.* acetanilid) which reduces the heart action and so relieves the pain by diminishing the blood pressure without removing the cause of the pain; for the real cause may be disordered digestion or eye strain. Cases of permanent injury and even of death have resulted from taking these headache compounds (Fig. 24).

106. Soothing sirups and cough medicines. — In most soothing sirups and cough medicines are found substances derived from opium, which is a powerful narcotic. Hence, children who are given soothing sirups often become stupefied. If these compounds are given frequently, they injure the child permanently, and in larger doses have caused death. If cough sirups and like compounds are taken often, an opium habit may be developed, which is even more difficult to overcome than is the alcohol habit.

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[1] "Smoking and Football Men." — *Popular Science Monthly*, October, 1912.

BEWARE OF ACETANILID

A large proportion of the most common headache medicines sold at drug stores depend for their effectiveness on the heart-depressing action of acetanilid. In some cases three or more grains of this drug are present in each dose.

The Pure Food and Drug Law requires all makers of patent medicines to indicate clearly on the labels of such preparations the presence of acetanilid and other dangerous compounds. Hence one has but to read the labels and avoid these nostrums in order to protect himself.

Take no headache remedy without consulting a doctor, unless you are sure it contains no acetanilid. Make the druggist tell you. He is responsible. A suit for damages has recently been won against a New York drug store for illness consequent upon the sale of a "guaranteed harmless" headache tablet containing three grains of acetanilid.

FIG. 24. — Acetanilid and other drugs in patent medicines.

107. Patent medicines as "bracers." — Figure 25 represents the percentage of alcohol contained in three "patent medicines" as given by the Massachusetts State Board of

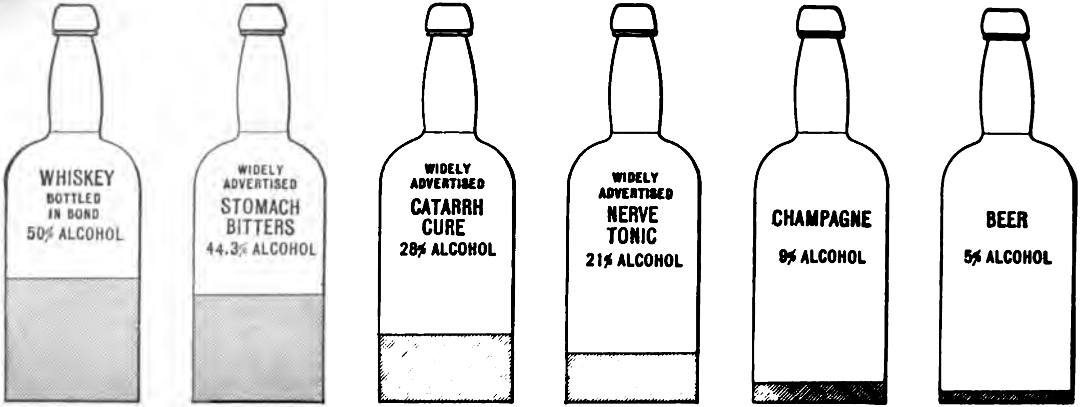

FIG. 25. — Percentage of alcohol in patent medicines and in liquors.

Health in published document No. 34, as compared with the percentages of alcohol found in whisky, champagne, claret, and beer. The stomach bitters (Fig. 25), for example, contained over eight times as much alcohol as that found in beer. Hence, the average drug store where these patent medicines are freely sold must share with the liquor saloon the heavy responsibility for the prevalence of the drink habit.

108. Pure food and drug law. — One of the most important laws passed by the 59th Congress of the United States was that which compels every manufacturer of foods or medicines to state on the label the composition of each. Analyses of foods and drugs have proved that hitherto many of them were largely adulterated by cheap and often injurious compounds, put in to increase the manufacturers' profits. Then, too, as already stated, many patent medicines contain high percentages of alcohol and other dangerous drugs. Under the new law the purchaser, if he takes the trouble to read the printed label, should be able to determine exactly what he is paying for and putting into his body.

109. Optional home work. — Examine the labels on any patent medicine bottles or boxes you can find. Make a list of such compounds as contain alcohol, opium, morphine, chloral, acetanilid, or phenacetin, and state after each compound the percentage of each of the drugs named.

CHAPTER V

DIGESTION AND ABSORPTION OF THE NUTRIENTS

I. GENERAL SURVEY OF THE DIGESTIVE SYSTEM

110. Necessity of digestion. — In Chapter III we discussed the composition, uses, and the preparation of foods. We learned in our study of plant biology (**P. B.**, Ch. IV) that certain of the food substances will readily pass through the walls of plant cells, while others will not. Hence, the latter, to become available for use in other cells, must be changed to soluble form, and this change we called *digestion.* We shall now discuss similar changes that take place in foods within our bodies; for before the different food substances can reach the cells of the brain, the muscles, or the bones where they are needed, they must be changed from a solid or semifluid condition into liquids that can pass through the walls of the cells that lie between the interior of the food canal and the blood. These necessary changes are accomplished within our bodies in the *alimentary canal,* a complicated tube nearly thirty feet in length.

111. Parts of the alimentary canal. — The alimentary canal (Fig. 26), as in the other vertebrates studied, begins with the *mouth opening;* it enlarges to form the *mouth cavity,* and this in turn communicates behind with a somewhat smaller *throat cavity.* Below the throat is the *gullet,* which conducts the food into an enlarged pouch, the *stomach.* Most of the lower half of the trunk is filled with the much coiled intestines which begin at the stomach and open to the outside of the body at the lower part of the trunk.

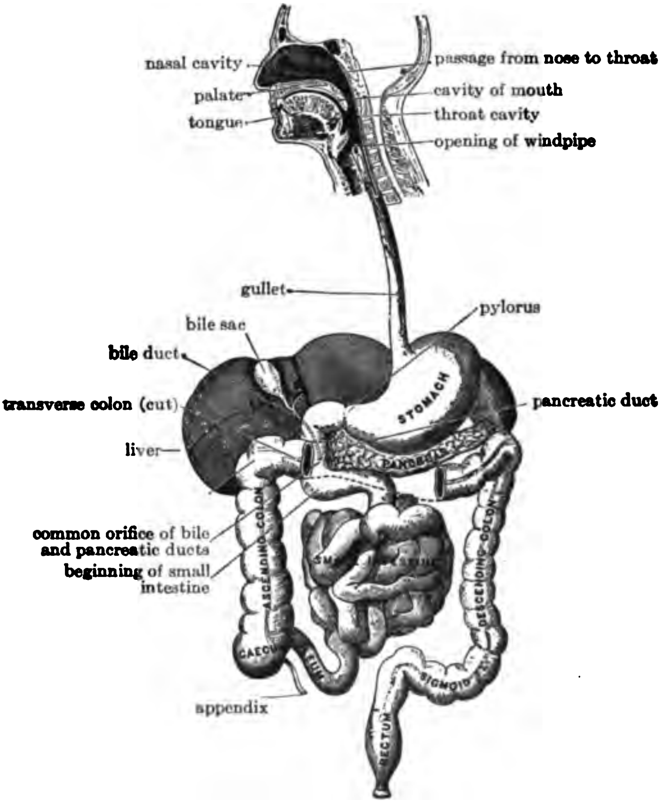

FIG. 26. — Parts of the alimentary canal. (The liver has been tilted upward to show the gall bladder on its lower surface; a piece of the large intestine has been removed to show the pancreas behind it.) Compare this figure with Fig. 2 which shows all the organs in position.

112. Digestive glands. — Several organs that are necessary in the process of digestion, as already discussed in the fish and frog, lie outside the alimentary canal itself, but are connected with it. These are the *digestive glands*. They produce *digestive ferments* (**P. B., 53**), which after being dissolved in water are carried into the food canal through small pipes or *ducts*. Thus the *salivary glands* pour their secretions into the mouth cavity, and the *liver* and *pancreas*, situated near the stomach, empty their juices into the intestine (Fig. 26).

II. THE MOUTH CAVITY AND ITS FUNCTIONS

113. Study of the mouth cavity. — (Home work.)

Take a position with your back toward a window or some bright light, and study your mouth cavity by means of a hand mirror.

A. *Walls of the mouth cavity.* — The walls that are rigid are composed largely of bone; those that are yielding are largely made of muscle.

1. Press your forefinger against the roof, the side walls, and the floor of the mouth cavity beneath the tongue Which walls are composed of bone? which of muscle?
2. What is the color of the inner walls of the mouth cavity? This color is due to the blood vessels that lie close to the surface.
3. Rub your finger over the *mucous membrane* which covers these walls. The substance on your finger is largely *mucus*. Describe the mucus and tell where it is found.

B. *Tongue.*

1. To what part of the mouth cavity is the tongue attached?
2. Chew a piece of apple or other solid food; note and describe the action of the tongue during the process of chewing food.
3. Swallow some solid food, and describe the action of the tongue in the process of swallowing.

114. Structure and functions of the tongue. — The tongue is an elongated mass of muscle tissue (Fig. 27). The muscle fibers run through it in three directions, and by their separate or combined action the free end of this organ may be moved about at will. When one examines the mucous membrane on the upper surface of the tongue, it is possible to see elevations of different sizes, called *papillæ*. Nerve fibers carry messages from these papillæ to the brain, and thus we become conscious of sensations of taste. Among the *carnivora* or flesh-eating animals the papillæ on the tongue are especially rigid. This enables the dog, cat, lion, or tiger to scrape the meat from the bones and to extract the marrow after the bones are broken open.

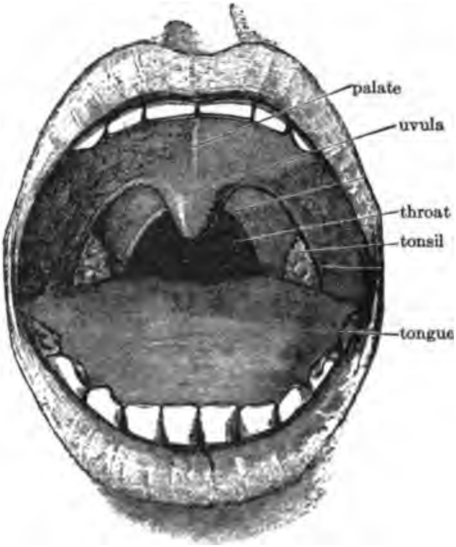

FIG. 27. — Mouth cavity.

115. Study of the teeth. — (Home work.)

1. Bite off a piece of apple or bread.
   a. Describe the motion of the lower jaw in biting off a piece of food.
   b. In what part of each jaw are found the teeth that are used in biting food?
   c. Describe the shape and cutting surface of these teeth.

2. Chew or grind a piece of apple or bread.
   a. Describe the motion of the jaw in grinding food.
   b. In what part of each jaw are found the teeth that are used in grinding or chewing food (Fig. 28)?
   c. Describe the shape and grinding surface of these teeth.

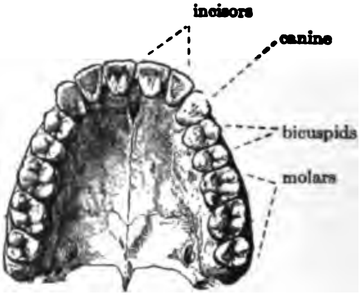

FIG. 28. — Teeth in upper jaw.

3. There are two kinds of cutting or biting teeth (Fig. 28), the *incisors* (Latin, *incisum*, from *incidere* = to cut into), and the *canines* (Latin, *canis* = dog, so-called because they often resemble the pointed teeth of a dog).
   There are also two kinds of grinding teeth, the *bicuspids* (Latin, *bi* = two + *cuspis* = point), and the *molars* (Latin, *molaris* = a millstone).

   a. (Optional.) Human teeth may be obtained from a dentist. They should be cleaned by boiling them in strong caustic soda solution, then in water. If possible, each student should examine and draw one of each of the kinds of teeth named above.

   b. Determine by the use of a mirror the number of teeth of each kind that you have and record the numbers in a table in your notebook as follows: —

	RIGHT HALF OF UPPER JAW	LEFT HALF OF UPPER JAW	RIGHT HALF OF LOWER JAW	LEFT HALF OF LOWER JAW
Incisors				
Canines				
Bicuspids				
Molars				

4. Examine carefully each of the teeth in your mouth and indicate in a table like the following the number of cavities (unfilled) and the number of fillings that you find.

	Right Half of Upper Jaw		Left Half of Upper Jaw		Right Half of Lower Jaw		Left Half of Lower Jaw	
	Cavity	Filling	Cavity	Filling	Cavity	Filling	Cavity	Filling
Incisors . .								
Canines . .								
Bicuspids .								
Molars . .								

116. Arrangement of the teeth. — Within the mouth cavity the solid food is cut into small pieces, mixed with the juices of the mouth, and then ground into a pulpy mass. A large part of this work is done by the teeth, which are arranged in two semicircular arches (Fig. 29). In a normal set of teeth each tooth in the lower jaw works against a corresponding tooth in the upper jaw, and this is very necessary in order to chew the food properly and to keep teeth and gums in a healthy condition. If, however, the teeth do not develop as described above, a competent dentist should be employed to correct the irregularities.

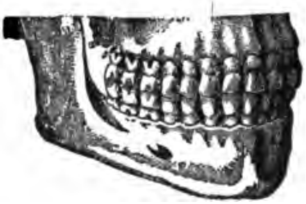

Fig. 29. — Arrangement of the teeth.

117. Milk teeth. — During early childhood there appears a first set of *milk teeth*, which later are gradually loosened and displaced by the growth of the *permanent set.* There are but twenty teeth in the milk set and their arrangement is as follows: —

	RIGHT HALF OF UPPER JAW	LEFT HALF OF UPPER JAW	RIGHT HALF OF LOWER JAW	LEFT HALF OF LOWER JAW
Incisors . . .	2	2	2	2
Canines . . .	1	1	1	1
Molars . . .	2	2	2	2

Bicuspids are, therefore, wanting, and the milk molars occupy the position in each half jaw that later is filled by the two bicuspids of the permanent set. The teeth appear gradually, the lower incisors usually being the first to push through the gums at about the sixth month. The third permanent molars of each half jaw often appear as late as the twentieth year; they are called the *wisdom teeth.*

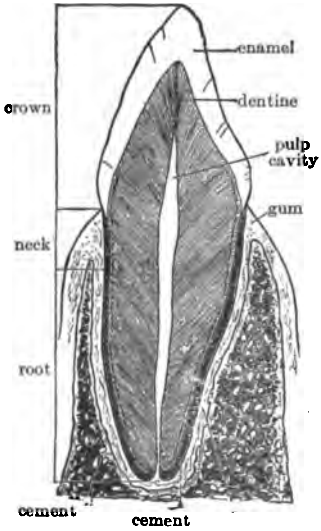

FIG. 30. — Longitudinal section of a canine tooth.

118. Structure of teeth. — The exposed portion of a tooth is called the *crown* (Fig. 30). It is covered with a layer of *enamel,* which is the hardest tissue in the body. The *root* of the tooth is imbedded in a socket in the bone of the jaw. It has no enamel, but, instead, its outer layer is a modified bone tissue called *cement.* The incisors and canines usually have but a single root, the bicuspids may have two, and the molars are often held in the jawbone by three, four, or five roots. In the region between the crown and the root is the *neck* of the tooth, which is surrounded by the gums.

The internal structure of the tooth is well shown in a vertical section (Fig. 30). The covering of enamel is thickest over the top of the crown; it becomes thinner down the exposed sides, and disappears in the neck region. The largest part of the tooth is composed of bony *dentine*. In the central part is the *pulp cavity*. This region is well supplied with nerves and blood vessels, which enter through a small opening at the end of each root. The blood furnishes the teeth with new building material.

119. Care of the teeth. — Too much stress cannot be laid on the importance of caring for the teeth, since decaying teeth are frequently painful, are always unsightly, are usually the cause of an ill-smelling breath, and often lead to indigestion. Immediately after eating, one should remove any bits of food from between the teeth by using a wooden toothpick, dental floss, or thread. Pins, knife-blades, or other metallic implements should never be used for this purpose. The teeth should then be brushed thoroughly on all sides, and warm water and a little castile soap or reliable tooth powder should be used. The sides of the teeth should be brushed from the gums toward the crown in order to avoid pushing the gums away from the neck of the tooth.

Since the enamel that covers the crown of the tooth is composed entirely of mineral matter, it cannot, of course, decay. If, however, food is allowed to decompose on or between the teeth, the acids formed by the action of the bacteria gradually dissolve the enamel until a cavity is formed. When the dentine is reached, the bacteria directly cause this part of the tooth to decay, since it contains living matter.

The teeth ought never to be used to crack nuts or to bite hard substances, for while the enamel is a very hard substance, it is also brittle and may be cracked or broken off by such treatment. If once lost, it will not grow again. It is evident, therefore, that it is very essential to protect this outer layer, both from the action of acids, and from mechanical injuries.

Some people seem to think that the loss of natural teeth is not a very serious matter, and that false teeth are just as effective as those teeth provided by nature. Experiments have shown, however, that the power to crush food with false teeth is only about one fifth that of the power exerted by a normal set of teeth. Hence, loss of teeth is very likely to result in imperfect mastication of food, with consequent ill-health resulting from indigestion. If, however, one has been unfortunate enough to have lost one or more teeth, the gaps should be promptly filled by bridge work. The teeth should be examined by a dentist at least *twice a year* so that any cavities found may be promptly filled. In short, *everything possible should be done to secure and preserve a beautiful and effective set of teeth.*

120. Importance of the digestion of starch. — In **47** of "Plant Biology" we proved that starch can not pass through the walls of cells, and we likewise showed in **49** how this food substance is made ready by the process of digestion to pass through membranes. Many of the foods we eat contain large percentages of starch. We are now to show experimentally how starch is digested in the human body.

121. Does saliva digest starch? — Laboratory demonstration.

Prepare some starch paste by boiling in a test tube of water an amount of arrowroot starch (or corn starch, if the arrowroot cannot be obtained) equal to half the size of a pea.

1. Pour a small amount of the starch paste into a test tube, add some Fehling's solution, and boil. Is grape sugar present? How do you know?
2. Put some saliva into a clean test tube. Test it with Fehling's solution as you did the starch. Does this saliva contain grape sugar? How do you know?
3. In another clean test tube pour some saliva into some of the starch paste, shake the mixture, and warm it gently for a few moments to the same temperature as that of the mouth. Now test with Fehling's solution, as in 1 above.
   - *a.* State what was done, the result, and the conclusion.
   - *b.* What, therefore, is the effect of saliva on boiled starch?
   - *c.* Name several foods already studied that could be partially digested by saliva.
4. (Optional home work.) Take some popped corn or shredded wheat into the mouth and chew it thoroughly. Can you detect any sweet taste at first? Can you after chewing for a time? What does this experiment teach you as to one advantage of thoroughly chewing the food?

122. Position and action of the salivary glands. — In addition to the mucus given out by the mucous membrane (**113**) the mouth receives another secretion called *saliva.* At the sight or smell of tempting food "the mouth waters." Saliva is secreted by the *salivary glands.* Two of these glands (the *parotids,* from Greek, meaning "beside the ear") are located near the back of the lower jawbone just beneath and in front of the ear. Any one who has had the mumps can readily locate these organs, for mumps is a disease in which these glands swell. From the parotid gland of each side a duct conveys saliva along through the walls of the cheek. This duct opens at the top of a small elevation, which may be felt with the tip of one's tongue opposite the upper second molar teeth.

Two other pairs of glands (the *submaxillary,* Latin, *sub* = beneath + *maxilla* = jawbone, and the *sublingual,* Latin, *sub* =

beneath + *lingua* = tongue) lie in the muscular floor of the mouth cavity, and the ducts from these glands open in the floor of the mouth under the tongue.

123. Uses of saliva. — (1) The saliva aids the mucus in keeping the mouth moist, and thus we are enabled to talk easily. (2) It moistens the food for swallowing. The importance of this function is appreciated when one tries to hurry in swallowing the crumbs of dry cracker. (3) Saliva helps to dissolve sugar and salt,[1] thus enabling us to taste them. If the tongue is wiped dry and a piece of sugar is placed upon it, we have no sensation of taste until the sugar has been partially dissolved by the mixture of saliva and mucus that is poured upon it. (4) Besides the three mechanical functions of saliva that we have just enumerated, this secretion digests cooked starch, as we have already shown. This digestive action is due to a ferment known as *ptyalin* (pronounced ty'alin) which acts in the same manner as the diastase found in plants.

III. THE THROAT CAVITY AND GULLET AND THEIR FUNCTIONS

124. Structure of the throat and gullet. — The cavity of the throat is behind the mouth. If one holds a mirror in front of the mouth opening and presses down upon the tongue with a spoon, one sees hanging down a small, fingerlike extension of the soft palate, called the *uvula*. When food is swallowed, this little tongue of the soft palate is shoved backward into a horizontal position, where it helps to separate the throat cavity from the nose cavity.

The lower part of the throat narrows into the *gullet*. This tube traverses the length of the chest cavity, and as it nears the stomach, it passes through the diaphragm. Like all other parts of the alimentary canal it is lined with mucous membrane, which furnishes a soft, moist surface for the passage of food. Outside the mucous membrane are rings of circular muscle running around the gullet.

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[1] See **130**, *A*, 1.

125. Functions of the throat and gullet. — The food is quickly forced out of the throat cavity into the gullet, and is pushed slowly down the gullet by the successive contractions of the rings of muscle just described. After being swallowed from the throat, the food does not drop into the stomach, for the walls of the gullet are pressed together by surrounding organs, except when this tube is opened by the passing food. In fact, after practice, one can swallow when standing on one's head, and most quadrupeds (horse, dog, cow), when feeding, hold the head below the level of the stomach.

IV. The Stomach and its Functions

126. Position, size, shape. — The stomach is a curved muscular pouch, which lies about midway between the upper and lower ends of the trunk, with its larger end lying toward the left side of the body, where it communicates with the gullet (Fig. 26). When moderately filled, this organ holds about three pints. The small intestine is continuous with the right end of the stomach, the communication between the two (known as the *pylorus*, from Greek, meaning gatekeeper) being controlled by a ring of muscle.

127. The lining of the stomach and the gastric glands. — If one examines with a lens the mucous lining of the stomach, a countless number of small openings are seen which look like pin pricks. These are the pores through which a digestive fluid known as *gastric juice* is discharged from the *gastric glands* (Fig. 31). This digestive fluid is composed of water

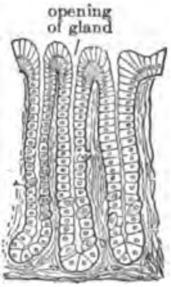

Fig. 31. — Three gastric glands.

(over 99 per cent), free *hydrochloric* acid and a digestive ferment called *pepsin*.

128. Muscles of the stomach. — The chief function of the human stomach is to secrete the gastric juice and to mix this juice thoroughly with the food. The muscular walls are well adapted for this purpose. When the food reaches the stomach, the gastric juice oozes out upon it, and the mixture is pushed back and forth and up and down by the successive action of the different layers of muscles. The return of the food to the mouth cavity is prevented by the contraction of the circular muscles at the lower end of the gullet, except in the case of nausea, when they relax and allow the stomach to rid itself of its contents. The circular muscle at the pyloric end of the stomach (Fig. 26) relaxes from time to time, and the partially digested food is pushed on into the intestine.

Fortunately for the well-being of the body, all these processes are entirely automatic; that is, they are carried on without our conscious direction. The muscles of the alimentary canal for this reason are called *involuntary* (Latin, *in* = without + *voluntas* = will).

129. Digestion in the stomach. — The gastric juice has practically no effect on the nutrients starch and fat. The saliva, however, that is mixed with the food and swallowed with it continues to act upon the starch for a time, particularly in the upper part of the stomach. Sugars and soluble salts (that is, salts that dissolve in water), if not dissolved in the mouth, are readily liquefied by the water of the gastric juice. Certain mineral food substances, however, like phosphate of lime found in milk, are not soluble in water, and these *insoluble salts* reach the stomach unchanged. The following experiment illustrates the way in which mineral matters are made liquid by the hydrochloric acid in the gastric juice.

130. Digestion of mineral matters. — (Optional.) Laboratory demonstration.

Note to Teacher: Part A should be demonstrated in connection with the study of saliva; Part B, in connection with gastric digestion.

Materials: Table salt, phosphate of lime, diluted hydrochloric acid (one part acid to six parts water).

A. Soluble mineral matters.

1. Put some table salt into a test tube, add water, and shake well. Does the salt dissolve? How do you know?
2. Saliva is largely (over 99 per cent) composed of water. How, then, are soluble mineral matters made liquid in the mouth?

B. Insoluble mineral matters.

1. Put some insoluble mineral matter like phosphate of lime (which is one of the constituents of milk) into a test tube, add water, and shake well, then allow the tube to stand for a time before answering the following questions.
   a. Does phosphate of lime dissolve in water? How do you know? Why is phosphate of lime called an insoluble mineral matter?
   b. Shake the mixture again and add some diluted hydrochloric acid. What change do you observe?
2. Hydrochloric acid is one of the ingredients of gastric juice. How, then, are insoluble mineral matters like phosphate of lime digested in the stomach?

131. Digestion of proteins. — One of the most important actions which takes place in the stomach is the digestion of proteins. This class of nutrients is not readily soluble in water and so cannot pass through the walls of cells (**P. B., 52**). Hence, before proteins can be made available for use in the body they must be changed to a soluble form known as *peptone* (P. B., 53). This chemical change is brought about in our bodies to some extent by the gastric juice.

132. Digestion of proteins. — Optional laboratory demonstration.

Materials: Boiled egg, powdered pepsin (which should be obtained fresh or kept in a tightly stoppered bottle), hydrochloric acid, water; test tubes. Each of the following experiments should be kept throughout the whole time as nearly as possible at the temperature of the body (98.6° F.).

A. *To prove that protein requires digestion after it is swallowed.*

1. Shave off with a knife and cut into the finest pieces possible a part of the white of a boiled egg (or better, grate the egg). The solid constituents of egg are largely protein. Put into a test tube a small amount (about twice the size of a pea) of this minced egg, add water, and shake. Label the test tube No. 1, and allow the mixture to stand for a day or two as nearly as possible at a temperature of 98.6° F. (which is the normal temperature of the interior of our bodies).
    - *a.* Has *all* the egg been made liquid or digested by the water? How do you know?
    - *b.* Pour off some of the clear liquid into a test tube, and add nitric acid and boil. Has *any* of the protein been digested? How do you know?
2. Into another test tube put the same amount of minced egg, add a spoonful or more of saliva. Label it test tube No. 2. Shake and allow it to stand for a day or two beside test tube No. 1.
    - *a.* Is protein digested by saliva? How do you know?
    - *b.* What do you therefore conclude in regard to the possibility of protein-digestion by the saliva?

B. *To prove that gastric juice digests protein.*

1. Into a third test tube put a small amount of the minced egg. Half fill the tube with water, add powdered pepsin to

the amount equal to about the size of a pea, and also add five to ten drops of diluted hydrochloric acid. (Water, pepsin, and hydrochloric acid are the three principal ingredients of gastric juice.) Label the test tube No. 3, shake the mixture, and put it in a warm place beside test tubes 1 and 2. (Since it is difficult to get the exact proportion of the three ingredients of gastric juice, it is well to prepare several tubes as described above, labelling each test tube No. 3.) At the end of a few hours or a day examine the test tubes containing the minced egg and the artificial gastric juice, comparing them with test tubes 1 and 2. Has the egg been digested? How do you know?

V. THE SMALL INTESTINE AND ITS FUNCTIONS

133. Position, form, and size. — The small intestine is a much-coiled tube, filling the larger portion of the abdominal cavity (Fig. 2). It is usually twenty feet or more in length, and therefore constitutes nearly four fifths of the whole length of the alimentary canal. Beginning at the stomach, it decreases somewhat in size until it opens into the large intestine.

134. Peritoneum. — The whole abdominal cavity is lined with thin, smooth membrane called the *peritoneum*. Sheets of peritoneum likewise inclose the various organs found in the abdominal cavity, and help to connect these organs to the walls of the abdomen. *Peritonitis* is an inflammation of any portion of this membrane.

135. Digestion in the small intestines. — In the intestines important digestive processes are carried on (1) by the juices secreted in the glands found in the inner wall of the intestine (*intestinal glands*), (2) by the pancreatic juice secreted by the pancreas, and (3) by the bile secreted by the liver. All these juices, when mixed with the food in the intestine, bring about the digestion of fats and complete the digestion of starch and proteins.

The pancreas (Fig. 26) lies just below the stomach and extends from the region of the pylorus toward the left side of the body. Within the gland is secreted the pancreatic juice, which is poured out through a duct upon the food just after it enters the small intestine. Pancreatic juice digests three of the nutrients; namely, starch, proteins, and fats. Like saliva, pancreatic juice changes starch into sugar, and like gastric juice, it converts proteins into peptones. The heat of the body melts much of the fat before it reaches the intestine, but this liquid cannot be absorbed until it has been still further acted upon chemically by the pancreatic juice and bile.

VI. THE LARGE INTESTINE AND ITS FUNCTIONS

136. Position, form, and size. — The large intestine is the last portion of the alimentary canal. It is a tube five or six feet long, with a gradually decreasing diameter. Beginning in the lower right-hand region of the abdominal cavity as a sac-like pouch (Fig. 26), the large intestine passes upward on the right side of the body cavity to the lower surface of the stomach; it then crosses the abdominal cavity; a third portion continues downward on the left side. The large intestine then takes an S-shaped course and passes to the exterior of the body by a short, straight tube.

137. Vermiform appendix. — On the right side of the body, and connected with the beginning of the large intestine, is a small, tubular sac about the size of a lead pencil, and usually about four inches long (Fig. 26). From its more or less twisted shape it has received the name *vermiform appendix* (Latin, *vermiform* = worm-shaped). *Appendicitis* is a diseased condition arising from inflammation in the tissues of the appendix.

VII. ABSORPTION FROM THE ALIMENTARY CANAL

138. Necessity for the absorption of food. — We have now learned something of the processes of digestion. We have seen that the foods we eat are ground up in the mouth cavity by the teeth and thus made ready for the action of the various digestive juices. We have also demonstrated that sugars and soluble salts are dissolved in the mouth; that insoluble mineral matters are made soluble in the stomach; that starch is changed to sugar by the saliva and pancreatic juice; that proteins are converted into peptones by the pancreatic and gastric juices; and that fats are digested in the intestines by the combined action of bile and pancreatic juice. Were the food to remain within the alimentary canal, however, even though it had been thoroughly digested, it would still be, in a certain sense, outside the body, since this canal is a continuous tube opening to the exterior at either end. In order to furnish material for building and repairing the various tissues, the liquid nutrients must be distributed to the tissues wherever needed. This is accomplished through the agency of the blood system. We have now to consider the process of absorption, which includes the final steps whereby foods become a part of blood. *By absorption is meant the passage of the digested food through the lining of the alimentary canal, and through the thin walls of the countless blood vessels that lie close at hand.*

139. Absorption in the mouth, throat, gullet, and stomach. — While the mouth, throat, and gullet all have a moist lining, generously supplied with thin-walled blood vessels, relatively little absorption takes place in these regions; first, because only a small amount of the food has been digested, and secondly, because the food does not remain long enough in these organs for absorption to take place.

The food usually remains in the stomach for several hours, and one would naturally expect that a good deal of absorption would take place during this time. But we must remember that the contraction of the stomach muscles keeps the food in constant motion.

This movement, while favorable to digestion, diminishes absorption, because the liquefied food does not remain long enough in one place to be absorbed by the blood.

140. Absorption in the small intestine. — We, therefore, find that most of our food passes through the pylorus before it is absorbed. In the structure of the small intestine, however, we seem to find every possible provision for gathering up the nutrients. In the first place, the lining of this tube at intervals is elevated to form ridges that run two thirds of the way around the interior wall, and some of them project about a third of an inch into the cavity of the intestines (Fig. 2). Like little dams, they delay the onward flow of the food, and they also increase considerably the large surface for absorption.

The absorbing surface is multiplied still further by the *villi*. If one were to examine with a hand lens the mucous lining of the small intestine, one would see that the ridges and the depressions are covered with tiny, hairlike processes that give a velvety appearance to the surface. Each of these minute elevations is called a *villus* (Latin, *villus* = a tuft of hair). The villi are exceedingly numerous in the small intestine of man, the total number being estimated at four millions. The absorbent action of the villi may be compared with the absorption that takes place through the walls of the root hairs of plants. In structure, however, a villus is much more complicated than is a root hair.

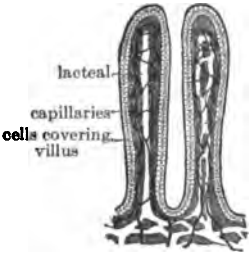

FIG. 32. — Two villi, highly magnified.

Each villus (Fig. 32) when highly magnified, is found to contain a network of minute blood vessels, and since they are covered only by a thin layer of cells on the outside of the villus, the liquefied food is readily absorbed by the blood current. Within the villi, too, are other thin-walled tubes, called *lacteals*, which are of great importance in the absorption of fats. As the souplike mass of food is pushed slowly along through the small intestine, it becomes less and less in bulk, and more and more solid, owing to the fact that the dissolved salts, sugars, peptones, and fats are largely taken up by the blood vessels and lacteals within the villi.

141. Absorption in the large intestine. — The amount of absorption in the large intestine is considerably less, of course, for both villi and ridges are wanting. Yet even here considerable absorption takes place. When the mass reaches the lower end of the intestine, it consists of little but the indigestible cellulose of vegetable foods, some undigested connective tissue, waste substances from the bile, the solids in the mucous secretion, and some raw starch and undigested fats if large quantities of these nutrients have been eaten. This refuse of the food is thrown off from the body.

VIII. THE LIVER AND ITS FUNCTIONS

142. Position, form, size. — The human liver (Fig. 26) is the largest gland of the body, weighing three to four pounds. It lies toward the right side of the body, just beneath the diaphragm, and partially covers the pyloric end of the stomach. It consists of several lobes, and on its under surface there is a small, greenish brown sac called the *gall bladder*. The deep red color of the liver is partly due to the fact that one fourth of all the blood of the body is found within its tissues.

143. Functions of the liver. — The liver performs three important functions. In the first place, it secretes a golden brown liquid called the *bile*, which is either poured at once through the *bile duct* into the small intestine or is stored in the gall bladder until needed. If the bile duct becomes stopped up, the bile is absorbed into the blood and gives to the tissues the yellow tint that is characteristic of *jaundice*. The liver, in the second place, serves as a great storehouse for the carbohydrates when the blood does not need them for immediate use. When, on the other hand, there is a lack of carbohydrates in the blood, some of the supply in the liver is taken up again by the blood. Finally, the liver helps to destroy some of the worn out cells of the blood (the red corpuscles), and the waste materials thus formed are passed off into the intestine as a part of the bile.

IX. HYGIENE OF DIGESTION

144. Hygienic habits of eating. — One should form the habit of eating slowly and of thoroughly masticating each mouthful of food. For by this process the food is thoroughly broken up, and thus is prepared for rapid digestion not only in the stomach but in the intestines as well. The process of chewing likewise stimulates the flow of saliva. Saliva not only helps digest food in the mouth, but this juice also, when swallowed with the food, continues for a time the digestion of starch in the stomach and likewise stimulates to greater activity the glands in the walls of the stomach.

At least a half hour should be devoted to the eating of dinner and twenty minutes to breakfast, lunch, or supper. The proper digestion of food depends in no small degree upon one's mental state; worry and disagreeable topics should, therefore, be forgotten as far as possible while one is eating, and the mealtime should be made a season of enjoyment. Regular hours of eating are of great importance, for nothing more commonly deranges the digestive system than the continual nibbling of food or sweetmeats between meals. One should refrain from vigorous exercise or mental exertion for some time after eating; the reason for this will be clear after a study of the blood system.

145. Prevention of disease. — To insure a state of health the useless residue of the food should be expelled from the large intestine regularly each day. If this is not done, serious disturbances of the health are sure to follow. By *constipation* is meant the abnormal retention of waste matter in the intestine. "The causes of constipation are imperfect digestion (due to deficient secretion in the alimentary canal, inaction of the liver, or insufficient contraction of the muscular fibers of the intestines), insufficient exercise, the use of alcohol or drugs, or improper food."[1]

Constipation may usually be counteracted by liberal drinking of water, especially a half hour before breakfast, and by eating food with laxative effect,—for example, ripe fruits (especially figs), green vegetables (especially salads with oil), and breads made of the coarser graham and rye flours.

Dyspepsia, also, is far too common, and is one of the most discouraging diseases to treat, because it shows itself in so many different ways. It is far easier to prevent than to cure, for it is usually caused by rapid or irregular eating, by taking indigestible foods, by lack of proper exercise, or by worry; and for all of these conditions the individual is, in the main, responsible.

The regulation of diet in time of sickness is a most important aid to recovery. In certain diseases it is necessary that some kinds of food should be forbidden. Whenever the functions of the body are not carried on with their accustomed vigor, the physician prescribes foods that are easily digested —for example, milk, raw oysters, toasted bread, and soft-boiled eggs.

146. The use of water as a drink.—"Many people, and especially many women, drink too little water. Water is constantly being lost through the lungs, skin, or kidneys, and this loss is only partially made good by the oxidation of the hydrogen of the proteins and fats. No rules as to the amount can be given, since it varies so much with temperature and the amount of muscular activity; but the habit of drinking no water between meals and but little at the table, in spite of popular opinion on the subject, is to be deprecated. . . .

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[1] From New International Encyclopedia.

"Undue emphasis has been laid upon the danger of drinking water with meals. The reasons given — that such water unduly dilutes the gastric juice or takes the place of a normal secretion of saliva — are questionable. As a matter of fact, the water thus taken is soon discharged into the intestine and absorbed. It is true, however, that the use of too much fluid with the meals is apt to lead to insufficient mastication because it makes it easier to swallow the food; and from this point of view caution is advisable. It is probably also true that much drinking with meals tends to overeating, by facilitating *rapid* eating." — HOUGH and SEDGWICK'S "Human Mechanism."

147. Effects of alcoholic drinks on the organs of digestion. — Alcohol, unlike most of the substances taken into the alimentary canal, requires no digestion. It can, therefore, be absorbed very rapidly by the blood, and hence alcohol is possibly sometimes of great value when administered by physicians, in cases when ordinary food cannot be digested. In health, however, alcoholic drinks must be regarded as an expensive and extremely dangerous source of energy.

According to the best authorities, small quantities of alcohol (when sufficiently diluted) seem for an adult to stimulate an increased flow of saliva and gastric juice, but even this is doubtful. The time required for the digestion of food, when alcohol is present in these small quantities, does not seem to be increased. Entirely different effects follow, however, when strong distilled liquors are taken, and alcohol in any large quantity often produces serious disturbances of the organs of digestion. This is especially true when liquors are taken without food; that is, between meals. *The constant danger that the moderate use of beer and the light wines will lead to an uncontrollable thirst for alcohol cannot be emphasized too strongly. All authorities agree, too, that the growing youth should let alcohol entirely alone.*

148. Review of Digestion

REGION OF ALIMENTARY CANAL	KIND OF SECRETION PRESENT	PROCESSES CARRIED ON
Mouth cavity.	Saliva and mucus	Mastication of food. Starch changed to sugar. Sugar and salt dissolved. Tasting of food substances. Small amount of absorption of water, salt, sugar.
Throat cavity.	Mucus.	Passage of food and air.
Gullet.	Mucus.	Passage of food to the stomach.

REGION OF ALIMENTARY CANAL	KIND OF SECRETION PRESENT	PROCESSES CARRIED ON
Stomach.	Gastric juice, consisting of water, pepsin, and hydrochloric acid, and mucus.	Churning of food by the muscles. Digestion of starch (by saliva, for short time). Proteins changed to peptones. Insoluble salts changed to soluble. Small amount of absorption of water, salts, sugars, peptones.
Small intestine.	Pancreatic juice, bile, intestinal juices and mucus.	Fats changed to a liquid form ready for absorption. Starch changed to sugar. Proteins changed to peptones. Large amount of absorption of fats by lacteals of villi. Large amount of absorption of water, salt, sugar, peptones, by blood vessels of villi.
Large intestine.	Mucus, and intestinal juices	Small amount of absorption of nutrients. Removal of refuse of food from the body.

CHAPTER VI

CIRCULATION OF THE NUTRIENTS

I. Composition of the Blood

149. Food and blood. — Thus far in our laboratory studies we have tested various foods, and have found that they all consist of one or more of the nutrients; namely, proteins, fats, carbohydrates (*i.e.* starch and sugar), fats, mineral matters, and water. We have discussed the way in which each of these nutrients is digested, and thus made ready for absorption into the blood — for until the nutrients actually become a part of blood, they cannot be of use to the body. In **7** we described the *red* and *white corpuscles* of the blood[1] (Fig. 5) and there stated that the liquid part of blood is known as *blood plasma.*

150. Composition of blood plasma. — Blood plasma contains a large amount of water in which are dissolved the various nutrients obtained by absorption from the alimentary canal. The presence of each of these nutrients has been demonstrated by applying the various food tests given in **23–28**, "Plant Biology." Following is the percentage of each nutrient found in the human body: —

Water	90^+	per cent
Proteins	8^+	per cent
Fats, grape sugar, mineral matters	2^-	per cent

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[1] For a laboratory study of blood, see Peabody's "Laboratory Exercises," pp. 50–53.

151. Hygiene of the plasma. — All the nutrition of the tissues is derived from the blood, and all the nutrients of the blood come from the foods we eat. If these foods are insufficient or of an improper kind, the blood will, of course, be deprived of necessary ingredients, and the cells must inevitably suffer in consequence. Hunger and thirst are the sensations that tell us that the blood is in need of new material. That this is true is demonstrated by the fact that these sensations disappear when water and liquid food, instead of being swallowed, are injected directly through the skin into the blood vessels.

152. Blood clotting. — When blood escapes from the body, it is a liquid of a bright red color. It soon changes to a dark maroon, however, and later this thickens to the consistency of jelly. This dark red mass is called a *blood clot,* and the process is known as *clotting* or *coagulation.* Coagulation is of great practical importance, since it provides a natural means of closing injured blood vessels, and of preventing loss of blood.

II. Circulation and its Organs

153. Necessity for the circulation. — From our study thus far, we have found that our bodies are composed of complex chemical compounds that are constantly being consumed in the development of heat and other forms of energy. It is evident, then, that every organ of the body, and indeed every living cell, must be supplied with new material to make good these losses and to provide for growth. The source of all this material is the food we eat.

In the last chapter we considered some of the processes by which foods are converted into liquid form and made ready for use in the cells. We found that after being liquefied these nutrients are absorbed by the blood vessels in the walls of the alimentary canal. Since, however, many tissues of the body are at a considerable distance from the organs of digestion, it is evident that some means must be provided for supplying each cell with the nutrients it needs. This is effected by the circulation of the blood. *By the term circulation of the blood is meant the ceaseless movement of the blood through a system of tubes called blood vessels.*

154. Organs of circulation. — As is also true in the fish and other vertebrates, the force that drives the blood around through the body is largely furnished by the contraction of the muscular walls of the *heart.* Any blood vessel that carries blood away from the heart is called an *artery.*[1] The *veins* are the blood vessels that bring the blood back to the heart. Connecting the arteries and the veins in every part of the body are countless microscopic blood vessels called *capillaries* (Latin, *capillus* = hair, so called from their minute size). We shall now consider in more detail the structure and action of each of these circulatory organs.

III. THE HEART

155. Position, size, shape. — The heart (Fig. 2) is a conical or pear-shaped organ about the size of the fist. It lies behind the breastbone near the middle of the chest cavity, with its pointed end or apex extending toward the left side between the fifth and sixth ribs. Since the beat of the heart is felt most plainly near the apex, it is commonly but wrongly believed that the heart lies on the left side of the body. Let one imagine the front wall of the chest cavity to be removed; one would then see the soft, pink lungs on either side, nearly filling the chest cavity, and between them the heart[1] (Fig. 2).

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[1] From Greek, *aer* = air + *terein* = to hold — a name which was given by the early anatomists to these tubes, because they were found empty after death, and were therefore supposed to carry air.

156. Chambers of the heart. — We have seen (**A. B., 99**) that a fish's heart has two chambers, an *auricle* to receive the blood from all parts of the body, and a muscular *ventricle* to force the blood into the arteries which carry it to the organs of respiration (gills) and thence by another system of arteries to all parts of the fish's body. In the human circulatory system, the blood, after returning to the heart from the organs of the body, is likewise forced through an auricle, a ventricle, and arteries, and so reaches the breathing organs (*lungs*). Unlike the circulation in the fish, however, the blood does not pass from the breathing organs to the other parts of the body directly, but returns by veins to the heart, and so another auricle and ventricle are provided on the left side of the heart. These receive the blood from the organs of respiration, and force it to all parts of the body. Thus we see that we have two hearts, the chambers of which are completely separated by a muscular partition; the right heart receiving the blood from all over the body and pumping it to the lungs; the left heart receiving the blood from the lungs and pumping it over all the body.

A comparison of these four chambers shows important differences. In the first place, the auricles have relatively thin walls as compared with the ventricles, and the reason for this is evident when we see that their function is simply to receive the blood from the veins and to push it downward into the ventricles. When one compares the walls of the left ventricle with those of the right, one is struck with the great thickness of the former. The left ventricle does much more work than the right; it forces blood to the top of the head, to the tips of the fingers and toes, and to every other organ of the body. The right ventricle, on the other hand, pumps blood only to the lungs (Fig. 33).

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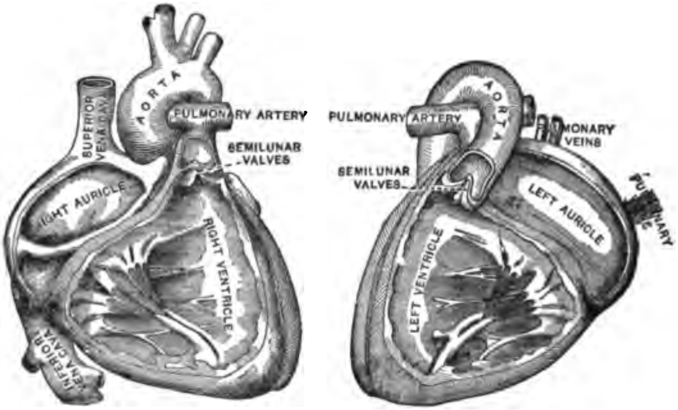
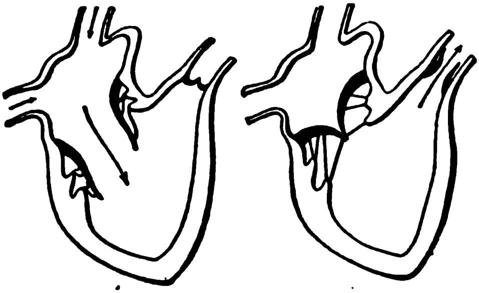
[1] The heart is not only surrounded by the skeleton and muscles of the chest wall, but it is also inclosed in a tough bag of connective tissue called the *pericardium* (Greek, *peri* = around + *cardia* = heart).



A = right heart. *B* = left heart.

FIG. 33. — Cavities of heart.

157. Action of the heart. — The blood flows into the right and left auricles and thence into the corresponding ventricles. When the ventricles are nearly full of blood, the two auricles contract and force downward enough blood to fill the two ventricles completely. These muscular chambers then contract and force the blood out into the arteries that lead to the lungs, or to other parts of the body. When the contraction of the ventricles takes place, it is evident that blood would be driven back into the auricles were there not some means of preventing this back flow. Hence, between each auricle and ventricle tough flaps of membrane are provided which close the opening while the ventricles are contracting. Connected with each of these flaps are tough cords of tissue that are attached to the muscular walls of the ventricle. These cords prevent the valves from being forced up into the auricle (Fig. 34). When the ventricles cease to contract, the blood entering the auricles presses these valves downward and so enters the ventricles.



A — positions of valves before the contraction of the ventricle.

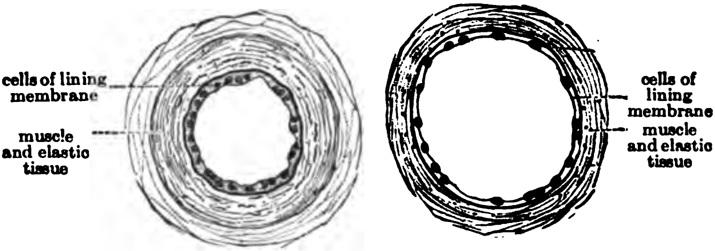
B — position of valves at the beginning of the contraction of the ventricle.

FIG. 34. — Diagrams to show the action of the valves of the heart.

IV. THE BLOOD VESSELS

158. Position of arteries and the pulse. — We have defined an artery as a blood vessel carrying blood *from* the heart. Every time the ventricles contract, the arteries leading from them are expanded, and this is true of every artery in the body. Most arteries lie beneath thick layers of muscle or bone, which protect them from possible injury; but in certain regions of the body they lie close to the surface. If one places the fingers on the wrist two inches or more below the ball of the thumb, it is possible to feel a distinct throbbing, called the *pulse*. This is due to the enlargement of the artery at each heart beat followed by subsequent contraction. When an artery is cut, therefore, the blood is forced out in spurts at each contraction of the ventricle.

159. Structure of arteries. — If a piece of the aorta of any animal is examined, it will be found that the blood vessel retains its tubular form, and this is due to the presence of thick layers of muscular and elastic tissue (Fig. 35). It is the elastic tissue that allows the arteries to expand when more blood is forced into them by the contraction of the ventricles. After each pulse these elastic walls squeeze the blood forward into the capillaries; arteries, therefore, are specially adapted to keep the capillaries full of blood.



A = artery. *B* = vein.

FIG. 35. — Cross section of blood vessels.

The muscular tissue in the walls of the arteries aids in regulating the size of the arteries, and so determines the relative amount of blood supplied to any given organ. For example, when the face is flushed, the muscles in the arteries have relaxed; pallor, on the other hand, is due to the contraction of the muscular walls.

160. A study of the pulse. — Laboratory and home study.

A. To take the pulse. (Laboratory study.)

1. Place the fingers on the wrist as directed in **158**, and count the pulse while sitting quietly for a minute, being careful not to miss any of the beats. Repeat the count several times, until the numbers approximately agree. Describe what you have done, and record your pulse rate in your notebook.

2. (Optional.) In a table like the following record the number of pupils with a pulse rate (while sitting still) corresponding to the headings of the various columns named below

40–49	50–59	60–69	70–79	80–89	90–99	100^{+}

B. To determine the effect on the pulse rate of different positions of the body. (Home work).

1. Lie a few moments on a couch and completely relax the muscles. Count and record your pulse, repeating the count till the number during a minute is reasonably constant. (It is better, if possible, to have some one else do the counting.)
2. In a similar way, make a record of your pulse while sitting.
3. Determine, likewise, the pulse rate when you are standing.
4. Take some vigorous exercise for a few moments (*e.g.* running upstairs or riding a bicycle).[1] Now determine your pulse rate.
5. What do you conclude, therefore, as to the effect on the heart beat of vigorous muscular activity? In what ways may the rate of the heart beat be decreased?

161. Valves at the mouth of arteries. — The arteries are always full of blood, and when the ventricles contract, these blood vessels have to be stretched in order to accommodate the additional blood that is forced into them. Hence, when the ventricles begin to relax, the blood tends to rush back into these chambers from the arteries. To prevent this, valves are placed at the opening of each of the two arteries that lead from the right and left hearts (Fig. 33). Each valve is shaped like a watch pocket. The three open outward from the heart, but as soon as the ventricles begin to relax, the blood fills up the pockets, and the three valves, by meeting in the middle of each artery, keep the blood from returning to the ventricles (Fig. 33, *A*).

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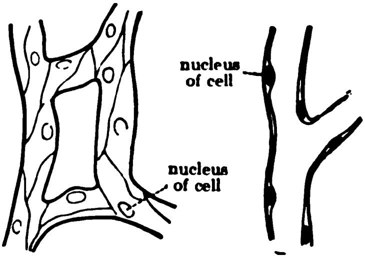
[1] In case the pupil has any heart difficulty, a milder form of exercise, such as walking rapidly or swinging the arms, should be taken.

162. Position of the capillaries. — As we trace the arteries farther and farther from the heart, we see that they divide and subdivide until very small branches are formed. That these fine branches are still arteries is proved by the fact that elastic and muscular tissues are present in their walls. Finally, however, these tiny blood vessels become continuous with still smaller tubes, the capillaries. So numerous are the capillaries that one cannot push the point of a needle for any considerable distance into any organ of the body without piercing a number of them. These smallest of blood vessels communicate freely with one another and form a complicated network of tubes that bring blood close to all cells of the body.

163. Importance of the capillaries. — If the blood were kept constantly within a system of tubes like the arteries, it would be entirely unable to help in the nutrition of the body because osmosis would be impossible. Each cell of the body must take from the blood the nutrients it needs for its special work; likewise it must give off to the blood the wastes it has formed by oxidation. It is through the thin-walled capillaries that all these exchanges of materials occur. Hence, the capillaries form the most important portion of the blood system.

164. Structure of the capillaries. — In structure the capillaries are extremely simple (Fig. 36). At the points in the blood system where arteries end and capillaries begin, muscular and elastic tissues are wanting. The walls of the capillaries are formed of a single layer of very thin-walled cells. We have in this arrangement the best possible conditions for the process of osmosis. Only the thin membrane of the capillary wall separates the blood from the surrounding tissues, and an exchange of materials between the two is readily carried on.



A — Surface view. *B* — Longitudinal section.

FIG. 36. — Structure of capillaries.

165. Position of the veins. — On the back of the hand one sees through the skin a branching system of bluish blood vessels. These are veins. Unlike the arteries, veins have no pulse. Many veins, like those in the hand, lie near the surface, while most of the arteries, as we have stated above, are buried deeply among the other tissues.

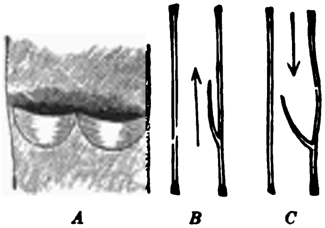


FIG. 37. — Structure of a vein.

A — vein laid open to show shape of valves; *B* — section of vein showing valve open; *C* — section of vein showing valve closing.

166. Structure of veins. — When the veins are emptied of blood, they immediately collapse. This is due to the fact that their walls have far less muscular and elastic tissue than have the walls of arteries. Veins, however, are provided with valves shaped much like the valves at the mouth of the large arteries leading from the heart. The blood can flow toward the heart, but as soon as it begins to pass in the opposite direction, these valves are immediately filled and thus the passage is obstructed (Fig. 37).

V. CIRCULATION OF THE BLOOD

167. Course of the blood through the body. — Having completed our survey of the structure and action of the heart and the blood vessels, we are ready to study the blood system as a whole and to learn how the blood goes to, through, and from, the organs of the body. Let us now follow the course of the blood from the time it leaves the left ventricle until it again returns to this chamber of the heart. When the left ventricle contracts, the blood is forced out into the largest artery of the body, which is known as the *aorta*. This blood vessel forms an arch (Fig. 38) from the upper portion of which branches extend to the head and the arms. The aorta then continues downward through the chest and abdominal cavities, supplying on its way the various organs in these regions. It then divides into two arteries that continue down the legs. Each of these larger arteries that we have mentioned divides again and again, until finally the blood is forced through a network of very fine capillaries in the various organs to which the arteries extend.

From these capillaries blood passes into tiny veins which carry all the blood into two large veins, one from the upper part of the body, the other from the lower part of the body; and these two veins finally empty into the right auricle of the heart. Thence the blood passes into the right ventricle.

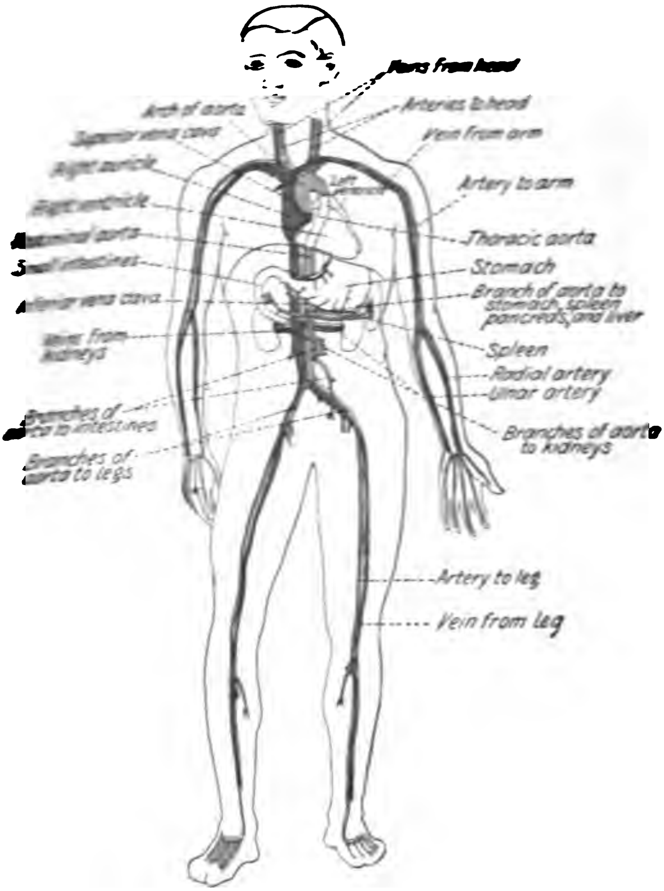


Fig. 38. — Diagram of the circulation to and from the various organs of the body except the lungs. Systemic arteries (red) and veins (blue).

The right ventricle by its contraction drives the blood through an artery to each of the lungs, until it finally reaches the countless capillaries in the interior of these organs. Veins now receive this blood and convey it to the left auricle, whence it again enters the left ventricle. About one half minute is required to complete the circulation.

168. Changes in the composition of the blood. — The composition of the blood is continually changing in its passage through the various tissues of the body. We may, perhaps, make clearer these various changes by expressing them in tabular form as follows: —

	BLOOD LOSES	BLOOD GAINS
In muscles, nerves, and other tissues.	Materials needed for growth, repair, and production of energy.	Wastes formed by oxidation (carbon dixoid, water, and other wastes).
In lining of mouth, stomach, intestines.	Materials needed for the manufacture of digestive juices and for growth and repair.	Digested nutrients.
In lungs.	Carbon dioxid and water.	Oxygen.
In kidneys and skin.	Water and other wastes.	Carbon dioxid.

VI. HYGIENE OF THE CIRCULATION

169. Effect of exercise on the heart. — The pulse rate is slowest when we are asleep. As the activities of the day begin, the heart beat is quickened, and after violent exercise this organ may beat as often as twice a second. Exercise, when properly regulated, is undoubtedly beneficial to every organ of the body, for the heart should be kept in such a vigorous condition that it is ready to meet not only the ordinary requirements of everyday life, but even the strain that may come in such emergencies as necessary escape from danger or recovery from disease.

It is easily possible, however, to overstrain the heart muscle by exacting from this organ too violent or too prolonged activity (*e.g.* in sprinting or in long distance runs and bicycle rides). These often result in permanent thickening of the walls of the valves of the heart. Before a youth takes part in athletic contests, he should consult a competent physician as to the wisdom of his taking violent exercise.

170. Effect of exercise on the blood vessels. — When one is using the muscles actively, greater oxidation of the tissues goes on, and a larger amount of blood is needed to supply the oxygen and to remove the added wastes formed by this increased oxidation. The muscular walls of the arteries relax in the organs that are specially active, thus supplying these organs with more blood. It is manifestly impossible to have an increased supply of blood in the organs of digestion, in the muscles, and in the brain all at the same time. This is the reason why it is unhygienic for an adult to exercise violently or to carry on any considerable degree of mental activity immediately after a hearty meal. Persistence in violating this rule usually results in attacks of indigestion.

171. Stopping of blood flow in wounds. — One can tell when an artery has been cut by the fact that blood comes out in spurts. Since the blood is on its way from the heart, the flow can be stopped or lessened in this kind of accident by applying pressure *on the side of the wound nearest the heart.*[1] Thus if the finger is cut deeply and the blood jets forth, a strong cord or a handkerchief should be tied loosely about the wrist, a wad of paper, or a pebble being placed directly beneath the knot and over the artery. A pencil or piece of wood should then be run through the loop, and the knot should be twisted until the blood flow is stopped by the pressure. When blood flows evenly from a wound, it is an indication that a vein has been cut, and the pressure should be applied in a similar way *on the side away from the heart.* If unable to decide whether an artery or a vein has been cut, put the bandage directly over the cut.[2]

Bleeding from the nose may usually be stopped by holding the head erect, and by applying cold water to the bridge of the nose or to the back of the neck.

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[1] Every pupil should practice the method of applying a bandage in accordance with the directions given in this section.

[2] For further treatment of cuts and bruises see **25.**

CHAPTER VII

RESPIRATION AND THE RELEASE OF ENERGY IN MAN

I. NECESSITY FOR RESPIRATION

172. To prove that oxidation takes place in the human body.[1] — Laboratory study.

A. Development of heat in the human body.

Secure two chemical thermometers that approximately agree at the room temperature. Support one of the thermometers so that it hangs free in the air; clasp the bulb of the other thermometer in the palm of the hand for several minutes.

1. Describe the experiment as it was performed.
2. Note and record the temperature as indicated on each of the thermometers.
3. What evidence have you that heat is produced in the human body?

B. Production of carbon dioxid in the human body.

Blow the breath through a tube into a bottle or test tube of lime water.

1. Describe what was done.
2. What proof have you that carbon dioxid is given off from the body?
3. What element found in foods and protoplasm must be oxidized in order to produce carbon dioxid?

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[1] The student should review **P. B., 75** (to prove that heat energy is developed in growing seedlings) and **P. B., 81** (to prove that carbon dioxid is formed during the growth of seedlings).

4. State now two evidences that oxidation is carried on in the human body.
5. What element must always be present in order that oxidation may be carried on?

173. Examples of energy in the human body. — While studying plants, we enumerated various ways in which these living organisms exhibit the energy which is developed within them (P. B., 74), and we have likewise called attention to evidences of energy in animals. In human beings the forms of energy are much more varied and striking. For example, the movements of each of the five hundred separate muscles found in the body are all due to the *muscular energy* developed in their protoplasm; the control of all these muscles is due to energy liberated in the nervous system (*nervous energy*); all the glands that produce the varied ferments owe their ability to do their work to the release of *chemical energy;* and when we come to deal with the highest functions, namely, feeling, thinking, and willing, it seems probable that all of them are made possible by the setting free of some form of energy. In connection with the development of all these forms of energy, heat energy, as we proved in **172**, is liberated.

174. Transformations of energy. — While considering the functions of green plants we found that the energy of the sun is utilized and stored in the manufacture of food materials, and thus is made available for the use of the plant. Consequently, when we take into our bodies and digest the various nutrients produced by green plants, these food substances become available as our sources of energy. But to release this stored-up energy, whether in muscle, gland, or nerve cells, oxygen is always essential. Hence, a constant supply of oxygen for the body is necessary. When this oxygen combines, in the process of oxidation, with the carbon, hydrogen, and other elements in the foods or protoplasm, waste matters (carbon dioxid, water, etc.) are produced, and for the healthy working of the body, these wastes must be eliminated. We are now to see how the body is adapted to secure an adequate supply of oxygen and to rid itself of harmful waste matters.

175. Respiration in plants, animals, and man. — It should be clear from our study thus far that all living things require oxygen, and that this oxygen brings about in plants, animals, and man a process resembling oxidation, at least in the releasing of heat and of other forms of energy, and in the production of carbon dioxid and other waste matters. These various processes doubtless take place in each living cell. Hence, every cell must be supplied with oxygen and must necessarily form carbon dioxid. *The process by which plants or animals take in oxygen and get rid of carbon dioxid is known as breathing.* And when we include also the oxidation that takes place within the cells and the elimination of the wastes from the cells, this whole series of processes is known as *respiration.*

Breathing involves two distinct processes; first, that of taking into the lungs new supplies of fresh air, and secondly, that of removing from the lungs the impure air that has been used. To the first process is given the name *inspiration* (Latin, *in* = into + *spirare* = to breathe); the second is called *expiration* (Latin, *ex* = out + *spirare* = to breathe).

II. ADAPTATIONS FOR SECURING OXYGEN AND FOR EXCRETING CARBON DIOXID

176. Course taken by the air. — In ordinary breathing, air enters the body through the two nostrils (the left one is shown in Fig. 39), and then through the two nasal passages it enters the throat cavity. In the lower region of the throat is the slit-like *glottis opening,* through which the air enters the *larynx* or voice box. The latter, commonly known as "Adam's apple," projects somewhat on the front of the neck. Below the larynx is the continuation of the windpipe, which, just above the level of the heart, divides into two main branches (Fig. 40), one of which supplies air to the right lung, the other to the left lung. Within the lungs these tubes branch off into a vast number of very small pipes, called *bronchial tubes.* The finest divisions of these tubes open into extremely thin-walled *air sacs* (Fig. 41).

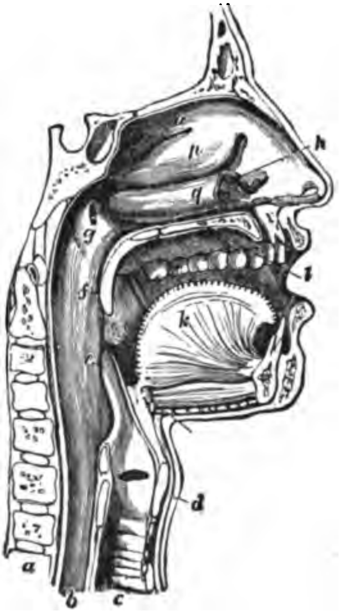

Fig. 39. — **Longitudinal section of head and neck showing food and air passages.**

a = **vertebral column.**
b = **gullet.**
c = **windpipe.**
d = **larynx.**
e = **epiglottis.**
f = **uvula.**
g = **opening of left Eustachian tube.**
h = **opening to tear duct.**
k = **tongue.**
l = **hard palate.**

177. The nose cavity. — The openings into the nasal passages are guarded by a mass of projecting hairs, by means of which a considerable amount of dust is kept from entering the lungs. The nose itself is lined by mucous membrane which covers the whole interior of the nasal chambers. Its mucous secretion collects most of the dirt and germs that have passed the hairs in the nostrils.

178. The throat and larynx. — Except when something is being swallowed, the glottis is always open, thus allowing a free passage for the air from the throat, through the larynx, into the windpipe. When food is swallowed, it is of course important that the windpipe be closed, and this is accomplished by a little trapdoor called the *epiglottis* (Fig. 39). If one puts the finger on the larynx region and then swallows, one can feel this organ rising to meet the epiglottis. Within the voice box are two thin membranes that may be stretched with more or less tension and set in vibration by the inspired or expired air. These *vocal cords* help to produce the various tones of the voice.

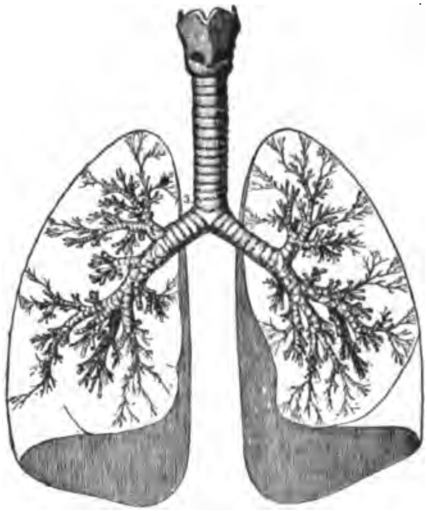

Fig. 40. — Windpipe and lungs.

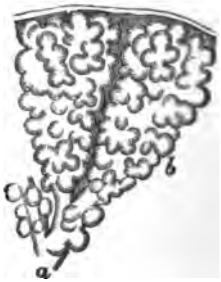

Fig. 41. — Two air sacs with their branches.

179. Lining of the air passages. — The mucous lining of the nasal cavities and of the windpipe and its branches is especially interesting. The cells that cover these passageways are covered by minute hair-like projections called *cilia*, much like those on the outside of a paramecium (**A. B., 120**), which wave upward toward the throat with a quick movement, and then more slowly recover their former position (Fig. 18). In this way any dust particles that have passed the barrier of hairs at the nostril openings and the mucus secreted by the membrane are moved steadily upward until they reach a point where they can be coughed out into the mouth cavity.

180. The lungs.[1] — When the finest branches of the bronchial tubes are traced, we find that each one ends in a branching *air sac* with extremely thin walls of elastic tissue (Fig. 41). When air comes into these sacs, they are expanded; but as expiration begins, their elastic walls help to force back through the branches of the windpipe the air that has been taken into the lungs.

181. Blood supply to the lungs. — The artery supplying the lungs, as we learned (**167**), arises from the right ventricle and soon divides into two branches, one for the right and one for the left lung. Within the lung tissue each artery divides into small branches that follow the course of the bronchial tubes to the air sacs. Here the arteries communicate with a maze of capillaries that run just beneath the thin lining of the air sacs. It is here that the exchange of material takes place between the blood and the inhaled air, for the two are separated only by the extremely thin walls of the air sacs and of the capillaries. From the capillaries of the lungs, the blood finally collects into veins that convey the blood to the left auricle.

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[1] One can get a good idea of the structure of the human air passages and lungs by securing from the butcher the chest organs of a sheep or calf. These consist of the larynx, windpipe, and its branches, and the two lungs, between which lies the heart. A piece of the diaphragm should also be secured if possible. The lungs are composed of soft, pink tissue, easily compressed by the hands. If air is forced through a tube inserted in the glottis opening, the lungs swell, and when fully distended occupy a space several times their size when collapsed. Just as soon as one ceases to blow into the lungs, these organs begin to collapse, and soon reach their former condition. The characteristics of the lungs and air passages should be demonstrated before **180** is assigned for study.

182. The function of red corpuscles. — In 7 we called attention to the structure of the red corpuscles of the blood. Like other cells red corpuscles are composed of protoplasm. Chemical analysis shows that the most important ingredient is a protein substance called *hemoglobin*, a compound that contains iron. Hemoglobin gives the red color to the blood and has a remarkable power of combining with oxygen when that element is abundant, and of giving it up wherever it is needed in the various parts of the body. We may, therefore, compare the blood corpuscles to countless little boats, floating in a stream of plasma; they take on their cargo of oxygen from the air in the lungs and discharge it in the cells of the tissues.

183. Change in the color of the blood after mixing with oxygen. — When the blood passes through the lungs, as already stated, it absorbs oxygen. The resulting change in color is seen from the following experiment. Pour into a glass bottle a small amount of blood that has been prevented from clotting by stirring it vigorously with a bunch of twigs, and stopper tightly. When the bottle is shaken violently, the blood is mixed with the oxygen in the bottle, and the dark maroon color changes almost instantly to a bright scarlet. The pupil will doubtless have observed that the blood in the veins on the back of the hand, for instance, is blue, but that whenever blood flows from any of these veins because of a slight cut, the color is always bright red after the blood comes in contact with the oxygen of the air.

184. Hygiene of the red corpuscles. — Since supplying oxygen to the various tissues is the function of the red corpuscles, it is very important that their number be sufficient and that they be kept in a healthy condition. To this end, *an abundance of sleep, exercise, fresh air, and nutritious foods are the essential conditions.* Every one is familiar with the fact that the face looks pale after loss of sleep, or when food and fresh air are insufficient, or during periods of physical inactivity, and this appearance indicates a lack of red corpuscles. Habitual paleness, or *a-næ'mi-a*, is a disease requiring medical treatment. It is frequently due to a want of iron in the system; hence, the value of spinach and other vegetable foods containing this element. Fresh air, a moderate amount of exercise, and good food are usually the best remedies for anæmia. A good complexion is, therefore, very largely dependent on healthy blood. Paint, powder, and other cosmetics will not give such a complexion; and besides cheapening the individual who uses them habitually, they are often a source of permanent injury to the skin and blood.

III. THE PROCESS OF BREATHING

185. Structure of the chest cavity. — In the upper portion of the trunk is the cone-shaped chest cavity, which is more or less inclosed by the breastbone, the ribs, the collar bones, and the spinal column. This bony framework is covered by muscles that help to move the ribs, and by the outside covering of skin. The floor of the chest cavity is formed by the tough sheet of muscle and connective tissue, the diaphragm. In this way there is formed an air-tight compartment, which is completely filled by the heart, the blood vessels, the gullet, and the lungs (Figs. 1 and 2).

186. The pleura. — The outer surface of each lung is covered with a thin layer of membrane, and the walls of the chest cavity are lined with the same kind of tissue. These two layers constitute the *pleura.* Both surfaces secrete a liquid which enables the lungs to glide over the chest wall without friction.

187. To determine the amount of enlargement of the chest cavity during inspiration. — (Home work.)

Force the air out of the lungs as completely as possible. Draw a tape or cord around the chest under the armpits, keeping it reasonably tight, and thus measure the girth of the chest.

1. State what you have done, and record in inches the measurement thus determined.
2. Inhale as much air as possible, and again record the chest measurement as directed above.
3. State the difference in the measurements thus obtained.
4. What is your conclusion, therefore, as to the amount of enlargement of the chest cavity?

188. How air is taken into the lungs. — The chest cavity is not like most boxes inclosed by rigid, immovable walls, for it may be enlarged in its three dimensions; namely, from side to side, from front to back, and from top to bottom. We shall now consider how this is made possible. A study of the skeleton will show that the ribs are joined to the vertebræ in the back of the chest region and to the breastbone in front in such a way that it is possible to raise and lower the front ends. When the air is forced out of the chest cavity, the front ends of the ribs are lowered and so the breastbone is pulled nearer to the spinal column. As we inspire, the muscles that run from the upper part of the trunk to each of the ribs contract, and so these bones are pulled upward toward a horizontal position. By this movement the breastbone is pushed farther away from the spinal column, and the ribs themselves press outward at the sides. In this way the capacity of the chest cavity is increased from side to side, and from front to back.

When the diaphragm is at rest, it forms a dome-shaped partition between the organs of the chest and those of the abdomen (Fig. 42). During inspiration, the muscles of which the diaphragm is largely composed, are made to contract, the dome of this organ becomes flattened, and so presses down upon the stomach, liver, and other abdominal organs, and these in turn force outward the wall of the abdomen. By the action just described, the size of the chest cavity is increased in its third dimension; namely, from top to bottom.

Thus, by the combined movements of the ribs and diaphragm, the chest cavity is enlarged in all three of its dimensions. The walls of the chest cavity would, therefore, tend to move away from the lungs; but the air already in the lungs expands the many air sacs in the lung tissue, and so keeps these organs in close contact with the chest walls. The moment, however, that the air sacs begin to enlarge, the air expands to fill the larger space, and so the pressure of the air on every square inch inside the lungs is diminished, and therefore becomes less than the air pressure outside the body. At once more air is forced in through the air passages until the pressure within and outside the body becomes equalized. This process we have described is called *inspiration*. Every inspiration requires muscular action in elevating the ribs and flattening the diaphragm.

189. To determine the breathing capacity of the lungs. — Laboratory demonstration.

Fill a large tray half full of water. Mark on a gallon bottle the level of 1, 2, 3, and 4 quarts; completely fill the bottle with water, and invert it in the tray, just as was done in collecting oxygen and other gases (**P. B., 10**). Beneath the mouth of the bottle insert one end of a glass or rubber tube. Now take in a deep inspiration, filling all parts of the lungs as completely as possible, then slowly exhale, blowing the breath through the tube. Make sure that only one complete expiration is carried on, and take care that all the expired air is collected in the bottle.

1. Describe the way the experiment was carried on.
2. Note the number of quarts occupied by the expired air in the bottle, and record this in your notebook.
3. What do you conclude, therefore, as to the amount of air that may be forced out of the two lungs of the individual who performed the experiment?

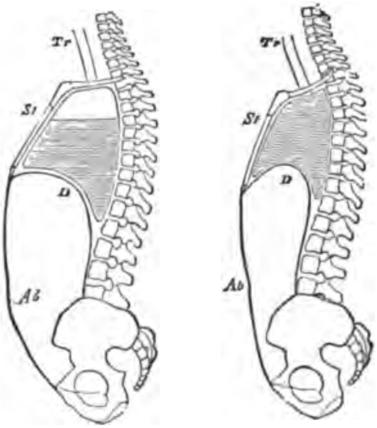
4. (Optional.) Ask the pupil who has the highest record of difference in chest measurement before and after inspiration (187) and also the student who has the least difference in the two figures, to try the experiment. State whether or not there is a correspondence between chest enlargement and lung capacity.

190. How air is forced out of the lungs. — As soon as the muscles that cause the upward movement of the ribs and the downward movement of the diaphragm begin to relax, the ribs sink back into their former position, the breastbone is pulled back into place, and the distended wall of the abdomen presses the organs upward against the diaphragm, which therefore becomes more arched (Fig. 42). In all these ways the walls of the chest cavity close in upon the lungs, and thus help their elastic tissue to force out the air in expiration. Ordinary expiration is thus accomplished without muscular effort.

IV. Hygiene of the Respiratory Organs

191. Hygienic habits of breathing. — We have called attention to the admirable provisions in the nose for filtering the air. Air is likewise warmed and moistened by the mucous membrane of the nose. This is necessary, because very cold or very dry air is irritating to the air passages and the lungs. Less efficient arrangements for this purpose are found in the mouth cavity. Hence, if one breathes through the mouth, one is likely to take in considerable quantities of dust and bacteria, which may, in time, cause inflammation or other forms of disease.

192. Effect of exercise on respiration. — Not only does the heart beat more rapidly during exercise, but the rate of breathing also increases. Oxygen is thus supplied to the cells in larger quantities, and more wastes are eliminated. Deep breathing is a prime requisite for healthful living, since in this way the air is changed throughout the lungs. In short, quick breathing, on the other hand, it is only the air in the upper regions of the lungs that is thus affected. The "second wind" that the runner gets after a short time is due to the expansion of all portions of the lung tissue. In order to keep the chest walls flexible and capable of full enlargement, a certain amount of regular exercise should be persisted in throughout life.



A = inspiration. *B* = expiration.

FIG. 42. — Diagram to show changes in the size of the chest cavity during inspiration and expiration.

Ab = abdominal wall.
D = diaphragm.
St = breastbone.
Tr = windpipe.

193. Effect of tight clothing upon respiration. — In an earlier part of this chapter we learned that air is forced into the lungs when the front ends of the ribs are elevated and the diaphragm is pulled downward toward the horizontal position. By no other means are the respiratory organs filled with air, and any interference with the action of either ribs or diaphragm tends to decrease the supply of oxygen and the excretion of carbon dioxid, and to increase the chances of disease in these organs. Tight clothing about the chest and abdomen not only results in permanent distortion of the skeleton (Fig. 46), but also it retards the movements by which the chest cavity is enlarged. Shortness of breath and inability to perform any great amount of muscular exercise are some of the ill effects that are experienced from tight lacing. Diseased conditions of the organs, too, may be brought about when they are thus compressed and forced out of position. It is especially important that loose clothing be worn in the gymnasium, or during any vigorous exercise, in order that the muscles used in motion and respiration may be free to work unhampered.

194. Diseases of the respiratory organs.—In **26–34** we discussed the cause, treatment, and prevention of pneumonia, diphtheria, and tuberculosis, all of which affect the organs of respiration. We shall now call attention to some other diseased conditions often found in these parts of our bodies. *Catarrh* is an inflammation of the mucous membranes of the throat and nose, and it sometimes becomes so bad that these air passages are more or less closed, and it causes a very disagreeable breath.

Within the nose and throat cavities projections from the walls frequently develop, which at times practically close these air passages and compel the individual to breathe through the mouth. These are known as *adenoids*. Between the mouth and throat cavities lie the *tonsils;* if these become unduly enlarged, and inflammation sets in, *tonsillitis* results. As soon as catarrh or enlarged tonsils or adenoids are discovered, the advice of a competent physician should be sought, for these diseases of the air passages prevent an adequate supply of air from reaching the lungs and tissues, and seriously interfere with the normal development of the body and mind.

Colds are inflammations of the air passages or of other regions of the body, and they are probably due to the action of bacteria. If the malady is confined to the nose cavity, we call it a cold in the head; if it is seated in the throat, a sore throat results; a cold on the chest is an inflammation of the windpipe or its subdivisions. When the bronchial tubes are affected, their lining membrane becomes swollen, and the air passages are more or less closed; this is *bronchitis.* And finally, if the inflammation affects the air sacs, *pneumonia* results.

195. Suffocation. — We have often called attention to the fact that the body must be supplied continually with oxygen and that its wastes must be constantly removed. If this process is interrupted, even for five minutes, fatal results are almost sure to follow. If, in swallowing, food gets past the epiglottis into the windpipe, *choking* results. In cases of this kind the head should be held forward (or downward in case of a child) and sharp blows struck between the shoulders. By *suf-fo-ca'tion* is meant some interference with the process of breathing. Suffocation may be due to inclosure in a small space with a limited supply of oxygen, to the inhaling of poisonous gases, or to immersion in water (drowning). In any case, the patient should be brought out at once into fresh air. If water has entered the air passages, the person should be turned face downward. One should then stand astride him and support the weight of his body by clasping the hands beneath his abdomen. In this position the water can flow out of his lungs more easily. If respiration is feeble, cold water should be applied to his face, and his chest should be slapped vigorously. If all these methods fail to restore vitality, and if the aid of a physician cannot be immediately secured, *artificial respiration* should be attempted at once.[1] This is accomplished by laying the patient on his back, with a rolled coat or other support beneath his shoulders. His mouth should be opened and his tongue drawn out. His arms should then be grasped firmly at the elbows and pulled upward and parallel to each other until they lie above the head. In this way air is drawn in through the nose and mouth. When the elbows are carried downward and pressed upon the chest, the air is forced out of the body. These two movements should be alternated regularly every few seconds, and hope of resuscitation should not be abandoned until several hours have elapsed.

196. Necessity of ventilation. — Every act of respiration removes oxygen from the air taken into the body, and adds to the air carbon dioxid and certain poisonous organic compounds. One might breathe in this air a second time and still be able to extract oxygen from it. The presence of chemically pure carbon dioxid in air even in considerable quantity is not necessarily dangerous; but to take into the body again the organic wastes that have once been given off is most unhealthful. The first effect of foul air is a feeling of sleepiness, followed by headache, and if larger quantities are breathed in, the body becomes poisoned. We see, then, the absolute necessity of having the air in a living room changed frequently. *The air that has been once used must be removed and a fresh supply must be furnished; this is what is meant by ven-ti-la'tion.*

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[1] Pupils should learn by actual practice on one another at home the movements necessary for causing artificial respiration.

197. Methods of ventilation. — It is important to remember that fresh air is not necessarily cold air, and that draughts of air in a room are not required; indeed, that they are undesirable. The problem of ventilation is that of furnishing a sufficient quantity of wholesome air of the proper temperature and moisture and of removing the foul air. It is evident that this is rather difficult to accomplish in schoolrooms or in public halls. Air will not of itself circulate rapidly enough, and so it has to be forced into these rooms by large blowers or revolving fans in the basement. This air should be filtered and moistened. Hot-air pipes or fans are likewise often employed at the top of the ventilating flues to draw out the foul air. Since warm air is lighter than cool air, the former should enter a room near the ceiling. As it cools it gradually settles toward the floor, and the openings into the ventilating shafts should be found at the lower part of the room. If the system works properly, there will be a continuous supply of clean, warm, moist air, and at the same time the air that has once been used will be drawn off through the flues.

Unfortunately, in most of our dwelling houses, little provision has been made by the builders for proper ventilation. Hence, if the rooms are heated by steam, we frequently breathe the same air over and over. This may be obviated, however, by ventilating in the following way. A piece of board two or three inches wide should be fitted across the lower end of the window opening. When the lower sash is pulled down upon it, a space is left between the upper and lower sashes, through which fresh air may enter the room without causing a direct draught. In order to secure a proper circulation of air an opening of equal size should be provided by lowering the top sash of the window.

Furnace heat is much more satisfactory than steam from the point of view of ventilation, for in this way a continual supply of fresh, warm air may be furnished. An open fireplace is one of the best means of removing foul air, and when a fire is burning, a strong current up chimney is assured. We have called attention to the fact that dry heat tends to cause catarrh and other diseases of the air passages. Provision should therefore be made to keep the air in rooms moist. This may be partially accomplished by keeping the water pans in a furnace full of water, or by leaving trays of water on steam or hot water radiators.

CHAPTER VIII

ADDITIONAL TOPICS IN HUMAN BIOLOGY

I. THE SKIN

198. Characteristics of the skin. — The whole outer surface of our bodies is incased in a flexible, elastic skin of varying thickness and texture. In regions like the palm of the hand and the sole of the foot, for instance, the skin is thick and tough; the covering of the lips, on the other hand, is extremely thin. At the ends of the fingers and toes are the nails. All other parts of the body, with the exception of the palms of the hands and the soles of the feet, have a covering of hair. Both the hair and the nails are modified parts of the skin.

199. Uses of the skin. — The most obvious use of the skin is the protection that it affords to the muscles and other organs that lie beneath. In the second place, it has a countless number of sense organs which receive messages from the outside of the body. These are carried along nerve fibers to the spinal cord and brain, and then we get impressions of temperature, of pressure, and of pain. In the third place, by means of the perspiratory action of the skin, the body throws off a great deal of water and small quantities of other waste matters. And, finally, as a result of the evaporation of this water from its outer surface, the body loses its surplus of heat, and so keeps an even temperature of 98.6° F.

As we might infer from all these uses, the skin is a complex organ composed of several tissues. We shall now study its structure and see how it is adapted to perform the *four functions* that we have just enumerated.

200. Layers of the skin. — The skin everywhere consists of two different layers: an outer, called the *ep-i-der′mis* (Greek *epi* = upon

+ *derma* = skin), and an inner, the *der'mis* (Fig. 43). When one gets a blister by burning the skin, most of the epidermis is lifted up by an excessive amount of watery fluid that comes from the blood. In a blister one can easily distinguish the white epidermis from the pink layers of the dermis lying beneath.

201. Glands of the skin. — Two kinds of glands are found in the skin; namely, the *oil glands* and the *sweat* or *per-spi'ra-to-ry glands.*

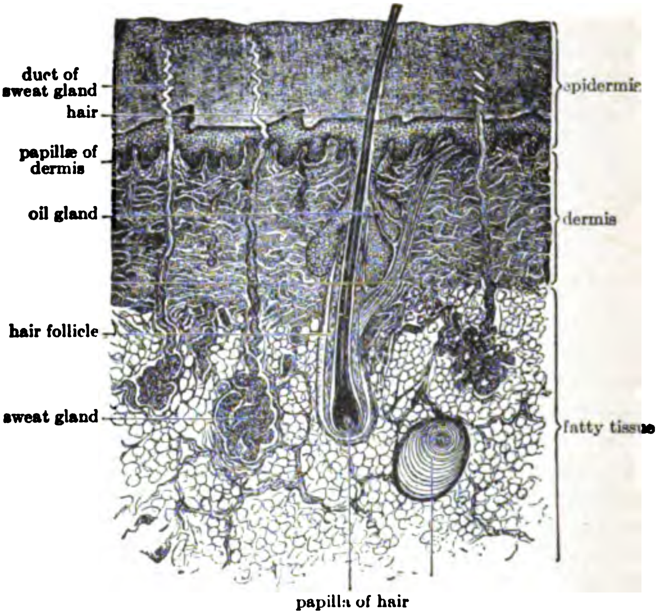


FIG. 43. — Vertical section of scalp, highly magnified.

The former are found in most parts of the skin, being most numerous in the scalp and in the skin of the face. Like hairs, however, oil glands are wanting on the palms of the hands and the soles of the feet. Sweat glands, on the other hand, are most numerous in the regions just named. One writer estimates that there are 2800 sweat pores on every square inch of the surface of the palm, and that the total number of these glands in one's skin is about 2,500,000.

202. Importance of bathing. — The oil glands and perspiratory glands are constantly pouring their secretions in greater or less quantity upon the skin. As the water evaporates, the oil and the solid ingredients of the sweat are left behind. Unless these are removed, they tend to clog the openings of the ducts from the glands and so to interfere with the work of the skin. A considerable amount of these substances is doubtless worn away, together with the scales of the outer skin, by friction against the clothing. But if the skin is to carry on its functions to the best advantage, and if decency is to be maintained, frequent baths must be taken.

203. Kinds of baths. — The oily secretions and much of the accumulated dirt on exposed surfaces of the skin can be removed only by the use of warm water and soap; hence these should be employed upon the hands two or three times a day and at least once or twice a week upon the whole body. *Warm baths* should be employed, however, for their cleansing effect only, since they are usually followed by a feeling of lassitude. One is much more likely to catch cold, too, after exposure to warm water, as it opens the pores of the skin, causes the arteries near the surface to dilate, and thus increases the amount of perspiration. Unless the warm bath is taken just before going to bed, it should be followed by a quick application of cold water.

Cold baths, on the other hand, if taken under proper conditions, have an exhilarating effect. The body should then be rubbed vigorously with a coarse towel. If after a cold bath one does not feel a warm glow, the bath is injurious rather than beneficial.

Baths should never be taken immediately after eating, since the blood is thereby drawn away from the organs of digestion. Nor should one remain in cold water until one feels a chill. *Shower baths*, however, are better than a cold plunge, for they stimulate both by the cool temperature of the water and by the force with which it strikes the skin.

204. Care of the hair. — The oil glands are most numerous in the scalp, and if the skin is in a healthy condition, the hair is supplied with the proper amount of oil. If this secretion dries, however, and becomes mixed with the loose outer scales of the epidermis, *dandruff* is caused, and this should be removed by vigorous brushing and shampooing. Not only is the scalp cleaned in both of these ways (if clean brushes and combs are used), but the friction stimulates the circulation of the blood through the scalp, and good blood is a better hair tonic than any external application. If the oil supply is insufficient and the hair becomes dry, vaseline may be used. The scalp should be well dried after a bath, for moisture at the roots of the hair tends to cause decomposition. Brushes and combs should be kept scrupulously clean.

205. Care of the nails. — One of the surest means of detecting slovenly personal habits is by watching the care an individual takes of his finger nails. An accumulation of dirt beneath the nails or jagged edges caused by biting the nails almost always indicate a lack of good breeding. The finger nails should be carefully cleaned with soap, water, and a nail brush or with a nail cleaner, but never with a penknife or scissors, for metal scratches the surface and makes a place for the lodgment of dirt. The roll of epidermis about the base of the nail should frequently be moistened and pushed back; otherwise this outer skin is likely to become torn and to form the so-called "hangnails." These are often a source of great discomfort and sometimes of danger, for they furnish a possible opening for infection by bacteria.

206. Treatment of burns. — We have already suggested the treatment for cuts and bruises of the skin in **25**. Another form of accident that may injure the skin is a burn. The affected part should be covered and bandaged with a paste of baking soda, which tends to lessen the pain by keeping out the air. A mixture (known as *carron oil*), half linseed oil and half limewater, is also a good remedy to keep on hand for burns. If, however, the skin is broken, the wound should be treated with an antiseptic. When the clothing of a person catches fire, the flames should be extinguished by wrapping him quickly in thick clothing or pieces of carpet.

207. Clothing. — The warmth of certain kinds of cloth depends upon the fact that they keep the heat of the body from escaping; in other words, they are poor conductors of heat. Good conductors, on the other hand, allow the heat to pass off rapidly. This difference in fabrics is largely due to the way they are woven. Wool, for instance, is usually made into cloth that is loose in texture, and thus it can hold a considerable amount of air in its meshes. Now, dry air is a poor conductor of heat. Woolen clothing is, therefore, generally used for winter wear. Cotton and linen are tightly woven, and heat radiation through these materials is rapid. When this takes place, the blood is likely to be driven away from the surface of the body, thus causing a congestion of blood in the internal organs, which is a favorable condition for such diseases as colds, pneumonia, or consumption. The same result often follows the wearing of wet clothing, since wet clothing is a good conductor of heat.

208. Effect of alcohol on body temperature. — "The action of alcohol in *lowering the temperature*, even in moderate doses, is most important. By dilating the cutaneous vessels, it thus permits of the radiating of much heat from the blood. When the action is pushed too far, and especially when this is combined with the action of great cold, its use is to be condemned."[1]

"A party of engineers were surveying in the Sierra Nevadas. They camped at a great height above the sea level, where the air was very cold, and they were chilled and uncomfortable. Some of them drank a little whisky, and felt less uncomfortable; some of them drank a lot of whisky, and went to bed feeling very jolly and comfortable indeed. But in the morning the men who had not taken any whisky got up in a good condition; those who had taken a little whisky got up feeling very miserable; the men who had taken a lot of whisky did not get up at all: they were simply frozen to death. They had warmed the surface of their bodies at the expense of their internal organs."[2]

[1] Landois and Stirling, "Textbook of Human Physiology."

[2] T. Lauder Brunton, London, "Lectures on the Action of Medicine."

II. THE SKELETON

209. Necessity for the skeleton. — Most of the common animals with which we are familiar have some kind of skeleton that serves as a means of protection, of support, or of locomotion. In some animals, *e.g.* clams and lobsters, the skeleton is on the outside; in the vertebrates, on the other hand, the skeleton is internal. A study of Figure 44 will make clear the general arrangement of the skeleton of man. The position and general shape of the bones may be determined by the pupil from a study of his own body. For convenience, the two hundred bones of the skeleton may be divided into three groups, namely, (1) the bones of the neck and trunk, (2) the bones of the arms and legs, and (3) the bones of the head.

210. The skeleton of the neck and trunk. — The erect position of the adult human body is maintained by a column of bones called *vertebræ*. The spinal column may be felt through the skin behind the neck and down the middle of the back. The human spinal column is a wonderful piece of mechanism, which by its structure is adapted to perform at the same time three distinct functions. In the first place, the vertebræ, piled one on the other, form a column strong enough to support the weight of the body. Again, the structure of the spinal column shows marvelous provisions for securing elasticity and freedom of motion. Elasticity is secured by a succession of four curves which are best seen in a side view of the body. By means of these curves the head and the upper part of the trunk are saved from sudden shocks that would result from running or jumping, for the curves act like a series of springs. Pads of cartilage between the vertebræ serve as cushions to prevent jarring. This general arrangement of the spinal column permits a considerable range of movement.

A third adaptation that is evident in the structure of the spinal column is the protection it affords to the delicate spinal cord (**231**) which is inclosed by it in a continuous tube. One would search far before finding a more perfect means of securing strength, elasticity, and flexibility than that provided in the structure of the human spinal column.

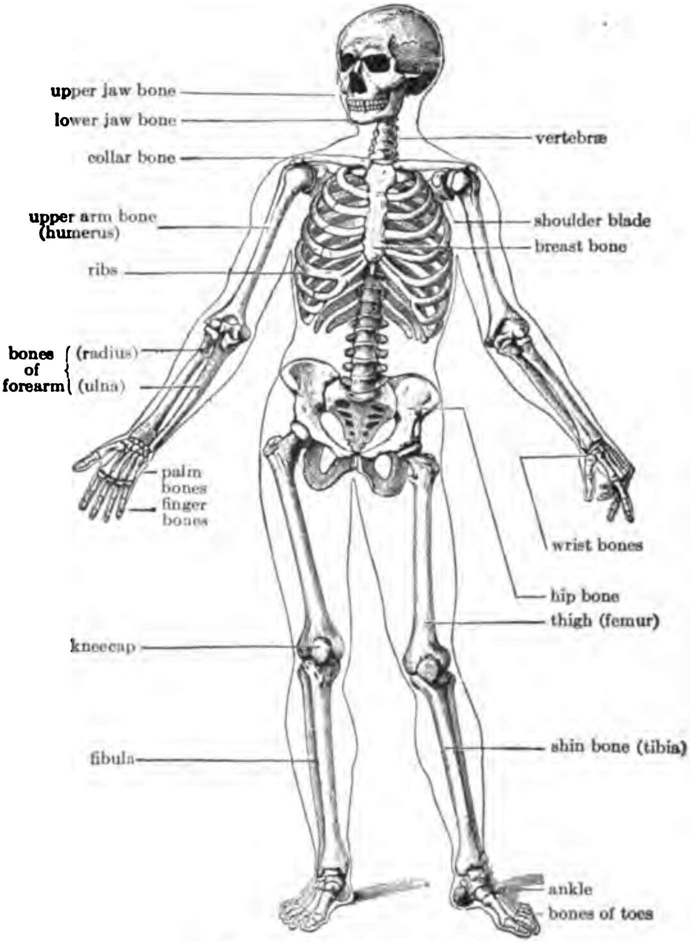


FIG. 44.—Skeleton of man.

Attached to the spinal column are twelve pairs of *ribs*, ten pairs of which connect with the *breastbone* and thus help to inclose the chest cavity (Fig. 44). The arms are attached to the rest of the skeleton by a movable girdle of bones consisting of the two *shoulder blades* and the two *collar bones*. A complete and rigid circle of bones is formed at the posterior end of the trunk by the two *pelvic bones*, which are attached dorsally to the spinal column and meet in front. On the outer side of each pelvic bone is a deep socket into which fits the upper end of the thigh bone (Fig. 44).

211. Skeleton of the arm. — The skeleton of the upper arm (see Fig. 44) is formed by a single long bone called the *hu'me-rus*, which extends from the shoulder to the elbow. In the forearm, one can feel through the flesh two separate long bones, of about the same size, lying side by side; the bone on the thumb side of the forearm is the *ra'di-us;* on the little finger side is the *ul'na*. Eight small bones are found in the wrist; and in the palm of the hand and in the fingers are nineteen somewhat elongated bones. All these twenty-seven bones move freely upon each other and thus give the hand a great freedom of movement.

212. Skeleton of the leg. — In the upper part of the leg (see Fig. 44) is a single bone, the *thigh bone* or *fe'mur*. This corresponds in position to the humerus of the arm, but it is longer and stouter than the latter; in fact, it is the longest bone in the body. The skeleton in the calf of the leg consists of two bones (*tib'i-a* and *fib'u-la*) which have a position similar to that of the radius and ulna. The tibia is on the inner or great-toe side and is much larger than the slender fibula. At the knee joint one can feel a flat piece of bone, more or less circular in outline, called the *kneecap*. The twenty-six bones of the ankle and foot are in the form of an arch, one end of which rests upon the heel.

213. Skeleton of the head. — Two groups of bones may be distinguished in the *skull* or skeleton of the head; namely, the bones forming the *cranium*, which surrounds and protects the brain, and the bones that form the *skeleton of the face* (Fig. 44).

By its rounded contour, the skull furnishes the best possible protection for the brain. In the first place, if a blow strikes upon the head, it would be much more likely to glance off than would be the case if the sides and top were flat.

Since the end of the nose and the outside ear are the most exposed portions of the head, they would, if made of bone, be in constant danger of getting broken. Cartilage, however, gives them sufficient permanence of form, and at the same time this elastic material, if bent out of shape, at once returns to its original position as soon as the pressure is removed.

The deep eye sockets seldom allow any blow to injure the eye. The drum of the ear, the three tiny bones of the middle ear, and the delicate mechanism of the inner ear are all buried deep in the hardest part of the skull, and so these are out of danger.

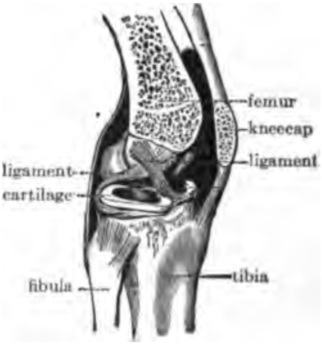


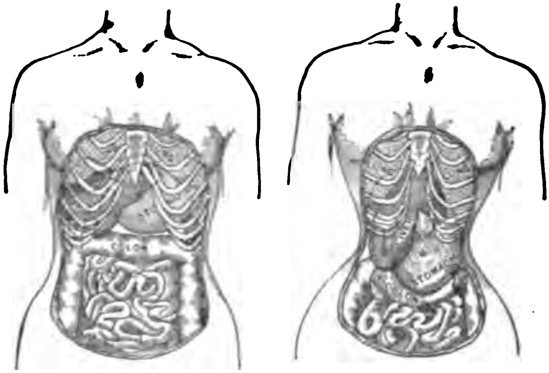
FIG. 45. — Knee joint.

214. Joints. — Thus far we have considered the bones of the skeleton as though they were independent of each other. In the living body, however, we know that they are firmly attached to one another by ligaments and muscles, and that thus a strong but movable framework is formed (Fig. 45). *Any region in the skeleton where motion is possible between two bones is called a joint.*

215. Food and the skeleton. — In the composition of bones, mineral is found to constitute about two thirds of the material, and this must be supplied by the food.

Milk is a most important article of diet in early life, since in addition to the other nutrients, it supplies the phosphate of lime needed for bone manufacture. In the process of refining wheat flour much of the mineral matter is lost; for this reason whole wheat flour and the coarser cereals like corn, rye, and oats are much more valuable as bone builders, and are especially needful during the period of growth. The mineral matters in our foods are made soluble and are then supplied by the blood to the bone cells, and these in turn convert this mineral matter into the hard intercellular substance.

216. Effect of pressure on bones. — Tight-fitting clothing is a most important factor in modifying permanently the shape and position of bones. Normal growth cannot be attained if the skeleton is subjected to pressure. Yet this important principle of hygiene is constantly violated by women who wear tight-fitting clothing about the waist. Baneful fashion is often followed even in youth, when the skeleton yields readily to pressure. The result is that the ribs are permanently bent downward and inward, thus interfering seriously with the action of the abdominal organs (Fig. 46). High-heeled shoes are another frequent cause of deformity. They reduce the spring in the arch of the foot and throw too much of the weight of the body upon the tips of the toes, and this is likely to injure the arch of the foot. Shoes with narrow toes should never be worn, since by this means the foot is deformed.



A — Normal position of organs. *B* — Position of organs after lacing.

FIG. 46. — Effect of tight lacing on the organs of the chest and abdomen.

217. Fractures. — Any sudden strain or blow upon a bone is liable to cause a break or a *fracture*, especially in later life, when the bones are brittle. Fractures occur more commonly in the shafts of long bones, and they may usually be recognized by the fact that an extra joint is thus formed and by the fact that the broken ends grate against each other.

In treating a fracture, the pieces of bone must be brought back into position (this is called " setting " the bone), and must be held in place by splints until the ends have become firmly " knit " together. The setting of a bone should only be attempted by a surgeon. In general but two rules should be followed in case of a fracture: *first, send for a doctor; second, keep the broken bone perfectly quiet in as comfortable a position as possible.* Hot or cold water applications if applied at once often reduce the pain and prevent inflammation. Movement at the point of fracture almost always causes inflammation, which makes the setting difficult; and if moved suddenly, the surrounding tissues may be injured as well.

218. Dislocations. — A *dislocation* is an accident to a joint in which the ends of the bones are forced apart. One can usually recognize a dislocation by the unwonted protrusion of the bones, and by the pain caused when any motion at the joint is attempted. Since ligaments of connective tissue bind the bones together rather closely, a dislocation often results in a wrenching or tearing of the connective tissue about a joint; swelling and discoloration follow quickly; and it is therefore necessary to put the bones back into place, or, in other words, to " reduce the dislocation " as soon as possible. If surgical aid can be procured, it is better to apply cold water to the joint and wait for the doctor's arrival, since by unskillful treatment further injury to the joint may result. When skilled treatment is impossible, most dislocations may be reduced by steadily pulling the bones apart until it is possible for the ends to glide back into place.

219. Sprains. — When a sudden strain causes neither a fracture nor a dislocation, it often gives rise to a twisting or tearing of ligaments and other connective tissues in the region of a joint. Such an accident is called a *sprain.* The injured region is usually swollen and painful. Since it is difficult to distinguish a sprain from other accidents to the skeleton, medical assistance should be summoned and the following directions carefully followed: (1) the sprained member should be placed at once in cold water or in hot water and held there for some time; (2) arnica or witch házel may be applied; (3) the sprain should then be bound in a tight bandage (these three applications tend to keep down the swelling); and (4) (most important of all) the joint should have *complete rest* until all swelling and soreness have disappeared. It is probable that more permanent injuries result from careless treatment of sprains than from all other accidents to the skeleton.

III. THE MUSCLES

220. Importance of muscle tissue. — Muscle tissue constitutes 41 per cent, or almost half, of the weight of the human body. In this kind of tissue is found one fourth of all the blood. But the importance of muscle tissue is appreciated, even more fully, when we realize that practically every kind of movement in the body is due to the action of the muscles. Not only do they bring about the more obvious motions of the arms (Fig. 47), the legs, the trunk, and the head, but also the contractions of the heart, of the stomach, and of the other internal organs. Every change in the expression of the face, and every variation in the tone of the voice, is likewise a result of the action of this all-important tissue. Hence we are not surprised that there are *over five hundred separate muscles,* which vary in length from the fraction of an inch (within the ear cavity) to over a foot and a half (down the front of the thigh).

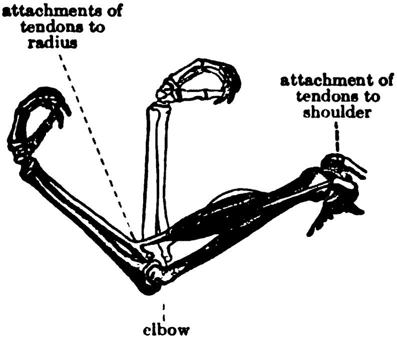

attachments of tendons to radius
attachment of tendons to shoulder
elbow

FIG. 47. — Action of biceps muscle.

221. Kinds of muscle. — All of these muscles are in one way or another under the control of the nervous system. Some of them are directed by the conscious portions of our brain. Thus we can close our fingers and open them as we please; we can move the eyes, the head, and the legs at will. We call all the muscles that are controlled by our will power *vol'un-ta-ry muscles* (Latin, *voluntas* = will). Most of the muscles of the throat, those of the gullet, stomach, and intestines, on the other hand, act without any voluntary direction on our part, and they are therefore called *in-vol'un-ta-ry.*

222. Conditions necessary for healthy muscles. — If one is to have a well-developed and healthy muscular system, four conditions must be fulfilled: *the body must be supplied with nutritious food; there must be a generous amount of fresh air; the muscles must be exercised vigorously; and this exercise must be followed by periods of rest.* We will now consider in turn how each of these requirements may be met.

223. Food.—We have learned that 75 per cent of muscle is composed of water, and that protein is the most important solid ingredient. Mineral matter and fats are also present in small quantities, even in the leanest of muscle. During the period of growth all these nutrients should be supplied for muscle building, but protein is absolutely essential. Grape sugar is also found to be an important food during muscular contraction. The diet of athletes while they are training for contests is carefully regulated: rare meats, coarse breads, eggs, vegetables, and fruits are supplied in generous quantities; pastry and fats are reduced to a minimum. Tobacco and alcohol in any form, however, are absolutely prohibited. Such a diet is undoubtedly far more wholesome to develop a healthy boy or girl, man or woman, than are the rich gravies, pastries, and condiments which are found on too many tables.

224. Fresh air. — Healthy muscle is absolutely powerless, however, unless, in addition to food, it receives a supply of oxygen; for all muscular energy is produced by oxidation. Impure air, besides being deficient in oxygen, contains carbon dioxid and other gases that are exceedingly harmful to the tissues (**196**). Well-ventilated sleeping rooms are most essential for healthy living, for during the night the body gets rid of much of the waste carbon dioxid that is formed during the day.

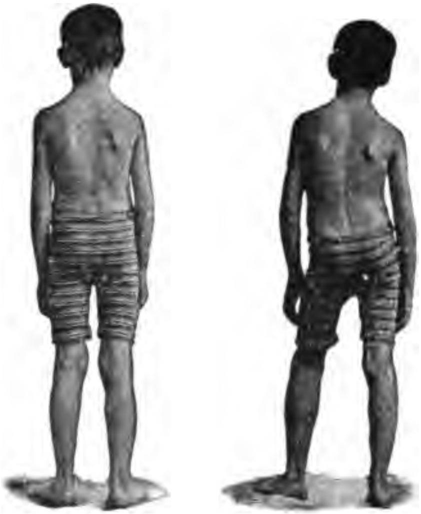
225. Exercise. — It seems like a contradiction to say that the only way to get more and better muscle is to destroy what we already have. Every one knows, however, that if the muscles of the arm or the leg are not used for a time, they become weak and flabby, and yet every time a muscle is made to contract, some of its substance is oxidized. New muscle, formed by the process of assimilation, must take its place.

A certain amount of vigorous exercise each day is essential if one's body is to be kept in the best physical condition. This amount, of course, varies with the individual, and it should never be carried to an excess, resulting in exhaustion. Fortunate is the boy who can spend the early years of his life in the country, and who has been taught to do a certain amount of manual work each day out of doors. Regularity in exercise is as important as regularity in eating. One cannot exercise vigorously one day and expect its good effects to last for a week. We should not call upon the muscles for violent exertion immediately after rising and before breakfast, nor should we exercise until at least a half hour after eating. The physiological reasons for these directions have already been given in our study of the circulatory system (**170**).

The best forms of exercise are those that call into play the greatest number of muscles. For this reason gymnasium training is better than many kinds of outdoor sports. In the gymnasium, too, special forms of exercise may be taken to develop any muscles found to be weak. On the other hand, lawn tennis, golf, rowing, and football have the additional advantage of being played in the open air, and games of this sort are usually more exhilarating than are set forms of exercise with apparatus. That the full effect of any kind of exercise may be attained, it should be followed by a moderately warm, then by a cold, shower, or sponge bath, and by a good rubbing of the body with a coarse towel.

Muscles are not the only tissues developed by exercise. Every muscular contraction is directed by some kind of stimulus from the nervous system. Before the muscles of the arm or leg contract, a " message " must come to them from the brain or spinal cord; hence nerve tissue is likewise developed by exercise.

226. Rest. — If physical exertion is carried beyond a certain point, exhaustion results, and the muscles cannot be made to contract until after a period of rest. Since all muscular contraction involves oxidation of tissue, periods of rest must be allowed for the muscles to get rid of their wastes and to build up new tissue in place of the old. The feeling of weariness after long-continued exercise is probably due to the presence in the body of great quantites of carbon dioxid, water, and other wastes. One can often rest to good advantage by changing from one form of activity to another, but from eight to nine hours of sound sleep each night are indispensable for the health of a growing youth. The necessity for sleep will be further discussed in the study of the nervous system.

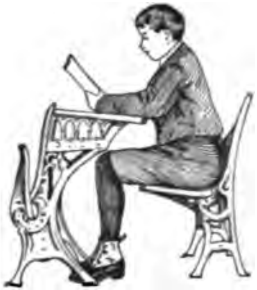


A = Correct posture. *B* = Incorrect posture.

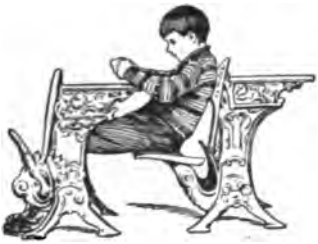
FIG. 48. — Standing positions.

227. Relation of muscles to proper posture. — An erect posture and graceful carriage not only add to pleasing appearance, but are important in maintaining the health. Round shoulders and stooping position decrease the capacity of the chest and interfere seriously with the action of its organs. It is important that boys and girls acquire a good posture early in life, and that they realize that *this* *is largely a matter of muscular training.* In standing (Fig. 48), the head and body should be erect, the heels brought close together, and the shoulders brought into such a position that the back is approximately flat. In sitting (Fig. 49), care should be taken not to bend the body over the desk, and a proper relation between height of chair and desk should be secured.

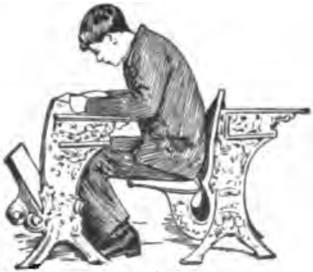
Permanent curvature of the spine frequently results from carrying loads of books or other heavy objects on one side of the body only; pupils should therefore train themselves to use the arms alternately for this purpose.



A = Correct posture.



B = Incorrect posture.



C = Desk and seat too low.

FIG. 49. — Sitting positions.

IV. THE NERVOUS SYSTEM.

228. The body as a collection of organs. — In the preceding chapters we have discussed the digestive, respiratory, and circulatory systems and have seen that these organs furnish all parts of the body with food and oxygen. We have studied the process of oxidation whereby we keep warm and gain the power to do work. And finally we are familiar with the fact that the bones and muscles are the organs that give support to the body and provide the machinery for all our motions. Thus we see that the body is composed of many organs, each with its special function or functions.

229. Coöperation of the organs. — But a human being is more than a mere collection of working organs, for *all the various organs work together for the common good.* This is what we mean by *coöperation* (Latin, *co* = together + *operari* = to work). Suppose we take a few instances from everyday experience to illustrate this coöperation.

When food is taken into the mouth, the salivary glands pour out upon it an abundant supply of saliva. Now, the food never comes in contact with the glands. How is it, then, that they send out their secretion at just the right time and in the proper amount?

If a blow is aimed at one's face, one's hands immediately fly up to ward off the threatened injury. If the attack were pressed and one were really compelled to defend himself, his heart would beat much more rapidly, he would breathe faster, and the flow of perspiration would become evident. During the contest certain feelings, also, would doubtless be aroused.

230. Functions of the nervous system. — All the succession of activities just described would be utterly impossible if some means were not provided for making the organs work together for the common good. The arms could not see to strike at the antagonist; nor could the heart, lungs, or skin respond to the sudden exertion of the rest of the body. It is the nervous system that controls the action of each of the organs in the body and brings about a coöperation between them. All our sensations, too, and our will power are doubtless correlated with the activities of the nervous system.

231. Parts of the nervous system. — The nervous system consists of *nerve centers* and *nerve fibers* (of which *nerves* are composed). The principal nerve centers are the *brain* and *spinal cord* (Fig. 50). These delicate organs are inclosed and wonderfully protected by the bony cranium and spinal column.

From the brain and spinal cord pass off numerous *bundles of nerves.* As they approach the different organs of the body they divide into branches, and thus the nerves become smaller and smaller. Finally, the microscope is needed to trace the individual nerve fibers to their endings in muscle, gland, or sense organ. By

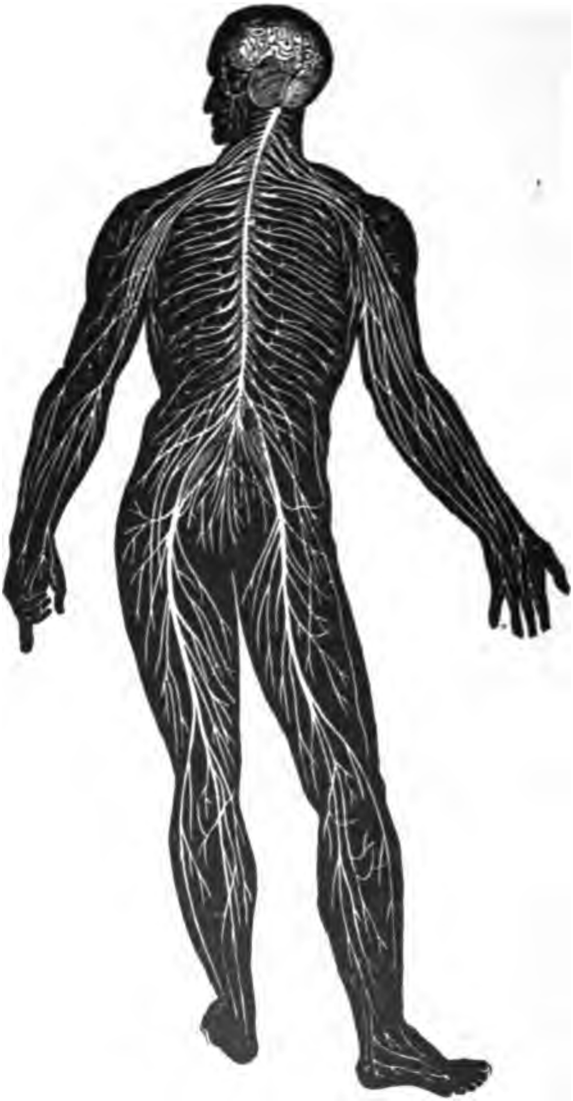


FIG. 50. — General arrangement of nervous system.

means of these countless nerve fibers all parts of the body are put in communication with the nerve centers (see Fig. 50).

232. Cellular structure of the nervous system. — If a section is made of any part of the brain or spinal cord, two kinds of material, known respectively as *gray matter* and *white matter*, may be distinguished. In the gray matter are countless *nerve cells* (Fig. 51) which are very irregular in form. From most of the nerve cells project numerous fine processes that look like tiny branching roots. These bring the various nerve cells into communication with each other.

One fiber-like process, however, has fewer branches than the others, and may be traced for a considerable distance from the cell body. This is the beginning of a nerve fiber, and it is the mass of nerve fibers that make up most of the white matter of the nervous system.

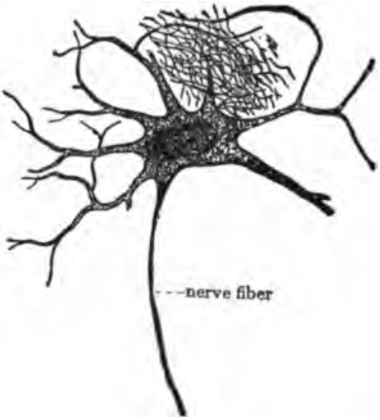


FIG. 51. — Nerve cell from spinal cord.

233. Nerve impulses. — We may compare nerve fibers to telegraph wires, and nerve impulses may be described as messages that pass along these fibers. But in making these comparisons we must remember that *telegraphy and the action of the nervous system have, in all probability, little real resemblance.* We know that nerves transmit impulses at the rate of about one hundred feet per second; electricity travels thousands of miles per second. Hence a nerve impulse cannot very closely resemble what we call a telegraph message. On the other hand, this nerve impulse travels much too rapidly to be explained as a chemical or mechanical action. We must therefore admit our ignorance of the real nature of the nervous impulse; nor do we know the real nature of the changes that take place in the nerve cells after receiving the so-called message. The principal functions of the brain may for convenience be divided into (1) reflex activities, (2) conscious activities, and (3) automatic activities or habits.

234. Reflex activities. — To illustrate the reflex action of the brain suppose we inhale some pepper; a message goes up the nerves to the cells in the nerve centers. This message is then reflected or switched off to cells which send impulses down the nerves that control the muscles of the chest. We then sneeze, and thus get rid of the pepper. Coughing, winking, blushing, the flow of saliva at the sight of savory food, — these are but a few of the reflex activites carried on by the brain.

235. Conscious activities. — As long as we keep awake, countless nerve impulses keep pouring into our brains. When the cells of the gray matter receive these impressions, we usually become conscious that we are seeing, smelling, hearing, tasting, or feeling. These sensations are more or less lasting, too, for we can recall distinctly the appearance of objects that we saw yesterday, or even years ago, and we can hear again, as it were, the sounds we have heard in the past. In some unknown way these impressions are stored away in the protoplasm of the brain, and constitute our *memory*.

Another power of which we are conscious is the ability to direct the movements of the body. We can rise from a seat, walk about, talk or change the expression of our faces as we will.

236. Habitual activities. — If we can remember the time when we learned to write, we recall that each letter was traced laboriously by a conscious effort of our brains to guide the muscles of our fingers. Writing, in our early years, belonged to the group of our conscious activities. But as time went on, less and less of our attention was needed for this mechanical process, until now our fingers seem to move of themselves. Walking, bicycle riding, swimming, playing the piano, conveying the food to our mouths — none of these activities require our attention. We have made these movements so many times that they have become *automatic*. In other words, the conscious part of our brains has trained other nerve centers to direct many of our everyday doings. Our attention is thus set free to carry on other kinds of work.

"As every one knows, it takes a soldier a long time to learn his drill — for instance, to put himself into the attitude of 'attention' at the instant the word of command is heard. But, after a time, the sound of the word gives rise to the act, whether the soldier be thinking of it, or not. There is a story, which is credible enough though it may not be true, of a practical joker, who, seeing a discharged veteran carrying home his dinner, suddenly called out 'Attention!' whereupon the man instantly brought his hands down, and lost his mutton and potatoes in the gutter. The drill had been thorough, and its effect had become embodied in the man's nervous structure."[1]

237. Importance of habit. — The tremendous importance of making our habits our allies instead of our enemies cannot be emphasized too strongly.

"The hell to be endured hereafter," says Professor James, "of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time!' Well! he may not count it, and a kind Heaven may not count it; but it is being counted, none the less. Down among his nerve cells and fibers the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral, and authorities in the practical and scientific spheres, by so many separate acts and hours of work. Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keep faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out."

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[1] Huxley's "Lessons in Elementary Physiology," Macmillan Company.

238. Conditions necessary for a healthy nervous system. — In studying the hygiene of other parts of the body, we found that four conditions were necessary for healthy activity. That the nervous system, too, may develop as it should and that it may do its work properly, the same four conditions are essential; namely, food, fresh air, various kinds of activity, and periods of rest.

239. Food and air.— In the nervous system of a human being there are millions of nerve cells. Each of these cells must be supplied with nutritious food and pure air, or it becomes stunted in its growth and unable to do its proper work. These busy cells are constantly giving off carbon dioxid, water, and other wastes, and if these are not removed and fresh oxygen supplied, one feels a drowsiness and headache, and is unable to think clearly. Well-ventilated rooms, both by day and by night, are of prime importance in the hygiene of the nervous system.

240. Varied activity. — To develop a well-balanced brain one must be active along many lines. Experience tells us, too, that we cannot work successfully at the same task hour after hour without some change. Hence, varied activity is an important principle in sound education. The young child must, of necessity, turn, after a short time, from one lesson to another, and all lessons must finally give way to the relaxation of play. Unfortunate is the boy who fails to find exhilaration in baseball, bicycle riding, or general athletics, for these sports, when properly regulated, besides developing strong lungs and vigorous muscles, are important means of educating the nerve cells and fibers.

Not only in youth, but throughout life, must the student, the business man, or the laborer, at the end of a day's employment, find relaxation in other forms of activity. If he fails to do this, not only will he become weary of his work, but he will also finally come to lose the power of enjoying the pleasures he has been neglecting. In the later years of his life, the great naturalist, Charles Darwin, wrote as follows: "My mind seems to have become a kind of machine for grinding general laws out of large collections of facts. . . . If I were to live my life again, I would have made a rule to read some poetry and listen to some music at least once every week; for perhaps the parts of my brain now atrophied would thus have been kept alive through use. The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature."

241. Rest. — Experiments with animals show a striking difference in the appearance of nerve cells before and after vigorous exercise. In the nerve cells of a bird that has been flying all day, the protoplasm has a distinctly granular appearance, which is not seen in the cells before exercise. Tired nerve cells can be restored by rest alone. In childhood and youth an abundance of sleep is absolutely essential for healthy development. Late hours of evening entertainment or of study should never be allowed to keep growing boys or girls from having at least nine hours of sleep.

242. Effect of alcohol on the nervous system. — "The effect of alcohol appears to be, as it were, to shave off the nervous system, layer by layer, attacking first the highest developed faculties and leaving the lowest to the last, so that we find that a man's judgment may be lessened, though at the same time some lower faculties, such as the imagination and emotions, may appear to be more active than before. . . . Thus you find that after a man has taken alcohol his judgment may be diminished, but he may become more loquacious and more jolly than before. Then after a while his faculties become dull; he gets stupid and drowsy. . . . Later on it affects the motor centers, probably the cerebellum, so that the man is no longer able to walk, and reels whenever he makes the attempt. At this time, however, he may still be able to ride (on horseback), and a man who is so drunk that he cannot walk and cannot speak may ride perfectly well. . . . Later on the further anæsthetic action of the alcohol abolishes sensation, and its paralyzing action destroys the power of the spinal cord, so that the man is no longer able even to ride; but still the respiratory center in the medulla will go on acting, and it is not until enormous doses of alcohol have been given that respiration becomes paralyzed.

"Alcohol . . . makes all the nervous processes slower, but at the same time it has the curious effect of producing a kind of mental anæsthesia, . . . so that these processes seem to the person himself to be all quicker than usual, instead of being, as they really are, much slower. Thus a man, while doing things much more slowly than before, is under the impression that he is doing things very much more quickly. What applies to these very simple processes applies also to the higher processes of the mind; and a celebrated author once told me that if he wrote under the influence of a small quantity of alcohol, he seemed to himself to write very fluently and to write very well, but when he came to examine what he had written next day, after the effect of the alcohol had passed off, he found that it would not stand criticism." [1]

V. THE EYES

243. Protection for the eye. — The delicate organs of vision, the eyes, are protected in a wonderful manner. In the first place, the eyeballs are set far back in bony sockets, in such a way that, even if one falls forward or if the face is struck with a large object, there is little danger that the eyes themselves will be hit. Again, each eyeball is covered by two movable lids that involuntarily close at any threatened danger. And, finally, the curving eyelashes on the edge of each lid protect the eyeball to a considerable extent from dust and dirt.

244. Structure of the eye. — Each eye is nearly spherical in shape (Fig. 52). Its outer surface is covered with a tough coat which is white in color, except in front, where it becomes the transparent *cornea.*

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[1] T. Lauder Brunton, London, "Lectures on the Action of Medicine," pp. 190, 191, 194.

Inside of the outer coat is a second layer which is seen beneath the cornea as a colored ring known as the *iris.* In the center of the iris is a circular opening, the *pupil,* which is black in appearance. Through the pupil enter the rays of light into the interior of the eyeball. If one comes suddenly from a dark room into the light, it is possible to see this opening quickly decrease in size. The inner lining of the eyeball is extremely thin and black in color; it is known as the *retina,* and connected with it are the many nerve fibers that carry messages to the brain.

Behind the iris is a beautiful transparent object, *the crystalline lens,* both surfaces of which are convex. The space within the eyeball in front of this lens is occupied by a liquid, and behind the lens is a jellylike substance.

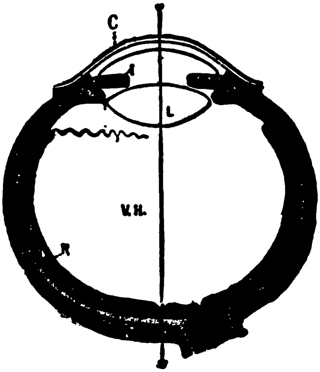

FIG. 52. — Section of the eye.

C = Cornea.
I = Iris.
L = Crystalline lens.
ON = Optic nerve.
R = Retina.
V.H. = Jellylike substance.

245. The eye as a camera. — Any one who is at all familiar with a camera knows that by means of a lens, or a combination of lenses, the scene to be photographed is made to appear upside down on the ground glass plate at the back of the camera. If the image is not clear, it is brought into focus by moving the lens nearer to, or farther from, the object.

In the eye, too, we have an arrangement similar to that of a camera, since the convex surfaces of the cornea and crystalline lens (Fig. 53) focus the rays of light so that an image is formed on the sensitive retina at the back of the eye. Since, however, the lenses within the eye cannot be moved backwards and forwards, as in a camera, focusing or *accommodation* of the eye must be accomplished in a different way, namely, by making the elastic lens more or less convex.

246. Sensations of sight. — We shall now try to see how it is that the eye helps us to get sensations of sight. If an object, say an arrow, is held in front of the eye, rays of light pass in a great many directions from every part of the arrow tip. A considerable number of these rays strike the convex surface of the cornea and the crystalline lens, and are thereby *focused*, or made to converge upon a point on the retina. In the same way the light rays from every other part of the arrow are brought to focus on the inner surface of the retina. By this means a *smaller, inverted image*, of the arrow (Fig. 53) is projected on the inner lining of the eye. The influence of these light rays then passes through the layers of the retina, and when these so-called " messages " traverse the nerve fibers and reach the brain, we become conscious of sensations of sight.

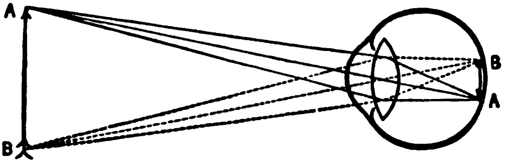

FIG. 53. — Formation of an image on the retina.

247. Defective eyes. — A normal, healthy eye has the power of adjusting itself so that objects become visible which are within five to ten inches, or as far away as a distant horizon. Many people, however, find that they can see objects near at hand much more clearly than those at a distance; in other words, they are *nearsighted*. Others, on the other hard, are *farsighted*. These defects in vision are due to imperfect formation of the eye, and can be corrected only by the use of proper *eyeglasses or spectacles, which should be purchased only on the recommendation of a competent eye specialist.*

Another very common defect of the eye is known as *a-stig′-ma-tism*. Many people, on looking with each eye separately at

Figure 54, find that some of the radiating lines stand out sharply defined, while others are indistinct or blurred. In reality, all the lines are equally distant from each other, and the indistinctness referred to above is due to the fact that some of the rays of light are not brought to a focus. Astigmatism, like nearsightedness and farsightedness, should be corrected by the use of proper glasses, otherwise constant eyestrain is likely to cause headaches and other disorders of the body.

Some people, too, are unable to distinguish clearly various colors; thus, red and green may appear the same to them. In other words, such people are *color blind.* Color blindness cannot be corrected by glasses, but may be to some extent by training.

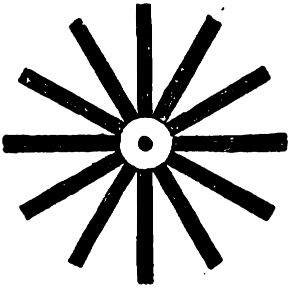

FIG. 54. — Test for astigmatism.

248. Hygiene of the eyes. — The eyes have, as we know, wonderful powers of adapting themselves to varying conditions. This adaptability often leads us to abuse them. Thus, we frequently read when the light is insufficient, we look steadily at objects until we suddenly find that we cannot see clearly, and we read or study while riding in swiftly moving trains. In these and other ways we compel our eyes to make adjustments under trying conditions, and more or less eyestrain is sure to follow.

When we read, we should make sure that the light is sufficient, that it is steady, and that it comes over the left shoulder. The type on the printed page should be little, if any, smaller than that in which most of this book is printed, the lines should not be close together, and the paper should not have a glossy surface to reflect the light into the eyes. One should remember, too, that the eyes, like other organs of the body, need frequent periods of rest. Hence study hours should be followed by periods in which the eyes are allowed to relax. Pupils who have defective eyesight should at once secure proper glasses.

VI. The Ear

249. The external ear. — Attached to each side of the head is an oval, more or less flattened expansion, composed largely of cartilage and connective tissue. The irregular surface of this outer portion of the ear doubtless helps somewhat, like an ear trumpet, to catch and converge the sound waves into the funnel-like canal which is about an inch long, and leads to the interior of the head.

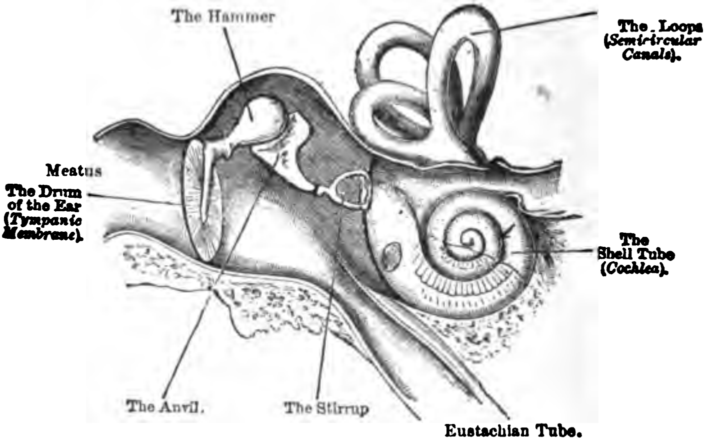
The Hammer
The Loops (Semicircular Canals).
Meatus
The Drum of the Ear (Tympanic Membrane).
The Shell Tube (Cochlea).
The Anvil.
The Stirrup
Eustachian Tube.

FIG. 55. — Middle and inner ear, greatly enlarged.

In the lining of this canal are certain *wax glands;* these secrete a thin fluid which, on thickening, hardens into a yellow paste, the *earwax.* Across the inner end of this tube of the external ear is stretched a thin membranous partition, known as the *eardrum,* or *tym'pa-num* (Latin *tympanum* = drum (Fig. 55)).

It is never safe for one to thrust into the canal of the ear any hard object, because of the danger of puncturing the eardrum. Ordinarily the canal cleans itself, but if it is necessary to remove bits of wax or dirt, this should be done with a tightly rolled corner of a piece of cloth. It is dangerous, too, to punish a child by boxing the ears, because the sudden compression of the air is likely to injure the drum. Earache is often relieved by hot applications; never should laudanum or other substances be put into the ear without the advice of a physician.

250. The middle ear. — Beyond the tympanum is a small cavity, known as the *middle ear*. From this cavity a narrow tube (the *Eustachian tube*) about an inch and a half long, communicates with the upper part of the throat cavity (Fig. 55). If one were to go up on a high mountain, he would find that the pressure of the air on the outside of the body, and therefore on the exterior of the eardrum, would become less, and if some of the air in the middle ear were not to escape, the eardrums would be forced outward, and hence would be ruptured. If, on the other hand, one should go into a deep mine, the increased pressure on the outside of the drums would force them inward. All these accidents are prevented by the presence of the Eustachian tubes, through which air can pass into and out from the middle ear, and so the pressure on both sides of the tympanum can be equalized. In severe head colds, the opening from the throat cavity into the Eustachian tubes becomes temporarily closed and we are then conscious of a ringing sensation in the ears. Catarrh sometimes closes the Eustachian openings and causes deafness. If the hearing seems to be at fault in any way, a specialist should be consulted.

251. Sensations of sound. — When a stone is dropped into water, the ripples move outward over the surface in circular waves. In a similar manner sound waves are transmitted in all directions from a given body, for instance, a vibrating bell. When some of these sound waves enter the tube of the external ear, they cause the eardrum to vibrate, and this vibration is transmitted across the middle ear by a chain of tiny bones, and so reaches the complicated inner ear, which is a series of canals imbedded in solid bone. The inner ear contains a large number of sensitive cells which transfer the vibrations to nerves communicating with the brain. When the brain cells receive and interpret these impulses, we get sensations of sound.

GREAT BIOLOGISTS

252. Library studies of biologists. — Select for study one or more of the following men who have made great contributions to our knowledge of biology: Agassiz, Aristotle, Audubon, Darwin, Harvey, Huxley, Jenner, Koch, Lamarck, Leeuwenhoek, Linnæus, Lister, Pasteur, Spencer, Wallace. Consult Locy's "Biology and its Makers," Williams's "A History of Science," Encyclopedias or other works of reference as to (1) the important events in the life of the biologist, and (2) his contributions to biological science.

LOUIS PASTEUR[1] (See Frontispiece)

I. Interesting Features of his Biography.
  1. *Parents.*
    a. Father (Jean Joseph), a tanner — sergeant major in Napoleon's army — decorated with Legion of Honor.
    b. Mother (Jeanne Rogui) of middle class family.
  2. *Birth,* at Dôle (in Eastern France), Dec. 27, 1822.
  3. *Education.*
    a. In colleges near his birthplace (Arbois and Besançon) — early evidences of remarkable ability in concentrating his mind in study.
    b. In colleges at Paris — much influenced by the scientists Dumas and Biot.

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[1] The ability to prepare *logical outlines* of library or laboratory studies is of great value to students (1) because in this form the principal facts can be stated more briefly than is possible in continuous paragraphs, and (2) because the various interrelations of the facts may be more clearly shown. In preparing such outlines the student should first select the most important division topics, all of which should be of equal value and expressed in similar form. Each of the various subordinate topics should be an organic part of the main division topic under which it is placed; each should be stated in a brief form, and as far as possible words or phrases should be used and verbs, clauses, or sentences avoided.

The outline on the life and works of Louis Pasteur is inserted (1) because of the importance of Pasteur's work, and (2) as a suggestive form for biology records.

4. *Professional work.*
   - *a.* Professor of Physics at Dijon (1848), and of Chemistry at Strassburg (1849).
   - *b.* Professor and Dean of Faculty at Lille (1854).
   - *c.* Scientific Director of Ecole Normale, Paris (1847), and Professor of Chemistry at Sorbonne, Paris (1867).
   - *d.* Director of Pasteur Institute, Paris (1888).
5. *Death,* at St. Cloud, Sept. 28, 1895.
6. *Position as a scientist.*
   - *a.* His life devoted to most important scientific investigations.
   - *b.* Highest honors bestowed upon him by men of science in all countries.
   - *c.* "The most perfect man in the realm of science."

II. Important Contributions to Biological Knowledge.

1. *Investigations relative to fermentation and decay.*
   - *a.* Fermentation formerly believed to be purely a chemical process, independent of the activity of living organisms.
   - *b.* Fermentation and putrefaction proved by Pasteur to be always due to the action of living microörganisms (yeast and bacteria).
   - *c.* Each kind of fermentation or decay demonstrated to be due to the activity of different kinds of germs.
2. *Discoveries relative to silkworm disease.*
   - *a.* Silk cultivation throughout France and Italy threatened by this disease.
   - *b.* Silkworm disease proved by long investigations of Pasteur to be due to minute germs infesting eggs, larvæ, pupæ, and moth of silkworm.
   - *c.* Disease eradicated by scientific treatment suggested by Pasteur.
3. *Researches relative to splenic fever among horses, cattle, sheep, and human beings.*
   - *a.* Rod-shaped bacteria found to be the cause of the disease.
   - *b.* Bacteria from the bodies of buried victims of the disease

proved by Pasteur to be brought to the surface by earthworms.

- *c.* Splenic fever checked by inoculating animals with a virus prepared in a manner somewhat like that of the virus of hydrophobia (see 4 below).

4. *Discoveries relating to hydrophobia* (*1885*).
   - *a.* Hydrophobia demonstrated to be a disease attacking the nervous system of victims bitten by mad dogs, wolves, or cats.
   - *b.* Solutions made from fresh spinal cords of animals thus bitten, on being injected into healthy animals always cause hydrophobia.
   - *c.* Spinal cords of animals dying of hydrophobia found to lose virulence (*i.e.* disease-producing power) after being dried.
   - *d.* Virus (*i.e.* glycerine solutions) obtained from spinal cords dried for varying lengths of time found to contain corresponding degrees of virulence.
   - *e.* Method of treatment for hydrophobia.
     - (*a*) Cauterization (burning) of wound with strong nitric acid.
     - (*b*) Injection on twenty-one successive days of virus of gradually increasing strength.
   - *f.* Result of Pasteur treatment in Paris; of 21,631 cases treated only 99 victims of the disease died, *i.e.* less than 1 per cent.
5. *Discoveries of other scientists directly due to Pasteur's work.*
   - *a.* Lister's methods of antiseptic treatment of wounds.
   - *b.* Koch's investigations as to the cause and treatment of tuberculosis.
   - *c.* Roux's and von Behring's antitoxin treatment for diphtheria.

APPENDIX I

LABORATORY EQUIPMENT

The laboratory. — It is very desirable that a definite room or rooms be set apart for work in biology, since at least a minimum equipment is essential, and this cannot be transferred from room to room without considerable loss of efficiency. While it is desirable to have tables or at least flat-topped desks of good size, satisfactory laboratory work can be done in an ordinary class room if it is well lighted. The laboratory should be supplied with a demonstration table and gas connection if possible, with sink and running water, and a broad shelf should be placed in front of the windows for supporting growing plants and aquaria, and for use in demonstrations with the compound microscope. Ample closet room should be provided in which to store apparatus and supplies, so that they may be kept free from dust.

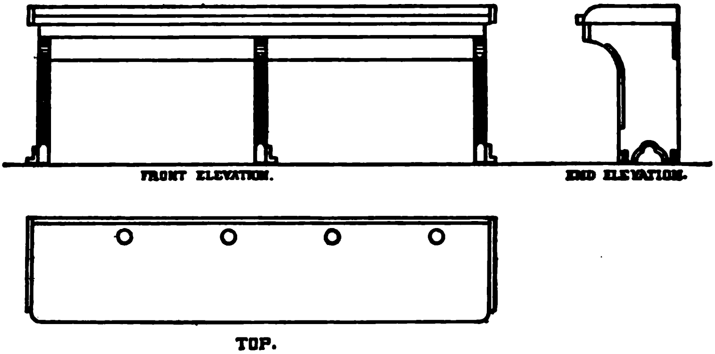

FIG. 87. — Plans for a laboratory table.

In case it is possible to equip a room with laboratory tables the following type is suggested. In the first place the laboratory tables should be firmly fixed to the floor, and arranged so that the light comes from the left side, and if possible also from the back of the room. The desk tops should be 30 inches from the floor and 20 inches wide, and should be made of maple or other hard wood. The length of each table will of course depend upon the dimensions of the room, but if possible no more than three pupils should be provided for at a single table. Each student should have at least 30 inches of the table space. (Fig. 87.)

" The finish of the laboratory table tops is a matter of importance, since it must be such as to protect the wood from damage, and keep it clean and smooth. Many prefer a black finish, to obtain which the following method gives good results.

"Make up solutions:

(1)	Copper sulphate ($CuSO_4$) . . .	625 grams
	Potassium chlorate ($KClO$) . . .	625 grams
	Water to make	5 liters
(2)	Anilin oil	300 grams
	Hydrochloric acid (HCl)	450 grams
	Water to make	5 liters

" Apply solution (1), followed immediately by (2) several times, until the wood becomes a dark green, allowing the applications to dry each time. The darker the tone reached, the better. The wood must then be washed thoroughly with soap and hot water applied with a brush. This is necessary in order to remove the superfluous salts. The table is finished with oil and will then be dead black."[1]

The advantages of the dull black finish are these: (1) there is little reflection of light from this kind of surface into the eyes of the pupils; (2) the black surface furnishes an admirable background for many objects of study; and (3) the tops are not injured by water, acids, or other chemicals.

Experience has shown that unless the laboratory must be used as an assembly room for a division at the beginning and close of school, drawers and shelves beneath the desk are of little real use, and often become mere receptacles for laboratory débris, unless they are provided with locks. It is usually far safer and more satisfactory to collect drawings, magnifiers, pencils, etc., at the close of the period, and to distribute materials as they are needed during the next period. If this work is properly systematized and the assistance of pupils is made use of, very little of the laboratory time is lost in this way.

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[1] From Lloyd and Bigelow's "The Teaching of Biology."

Seats fixed to the floor, likewise, are of great advantage. The authors have found that the best seat for this purpose is the Chandler chair, which is furnished by the American Seating Company, 19 West 18th St., New York City. It has a strong iron base, which can be screwed to the floor, and the chair seat turns on ball-bearings through an arc of 180 degrees. The price of the chair is $2.

Apparatus and chemicals. — The following lists of apparatus and chemicals are suggested as a minimum equipment for a class of 24. Most of the items can be purchased from any one of the following dealers:

Bausch and Lomb Optical Co., Rochester, New York.
Kny-Scheerer Co., 404 West 27th St., New York City.
O. T. Louis, 59 Fifth Avenue, New York City.

QUANTITY	APPARATUS AND GLASSWARE	ESTIMATED PRICE
1	Compound microscope, with ⅔- and ⅙-inch objectives, double nose-piece, 1 inch eye-piece, and revolving disk-diaphragm	$30.00
24	Magnifiers, doublets, 1¼-inch focus	16.20
1	Harvard trip-scale balance	6.00
12	Evaporating dishes, 3 inches diameter	1.50
1	2-quart agate double boiler	1.50
2	Alcohol lamps *or*	.50
2	Bunsen burners (if gas is available)	.40
3 ft.	Rubber tubing (heavy) to fit Bunsen burners	.60
144	Slides, plain, 1 × 3 inches	.80

1 oz	Cover glasses (round)	$ .70
12	Sloyd knives	2.25
24	Forceps (heavy)	5.00
12	Dissecting scissors	2.25
50	Handles (adjustable) for dissecting needles	2.00
100	Needles for handles	.25
144	6-inch test tubes	1.50
12	8-inch test tubes, hard glass	1.50
2	Chemical thermometers (Fahrenheit and Centigrade scale on same)	2.00
1	Lactometer	.50
1	Radiometer	1.10
2	Iron ring-stands (3 rings)	1.10
2	Pieces wire gauze (4 × 4 inches)	.08
2	Pieces asbestos (4 × 4 inches)	.07
6	Glass stirring rods	.10
25 ft.	Glass tubing, 5 mm. outside	.30
10 ft.	Rubber tubing to fit glass tubing	.70
12	Thistle tubes (medium size)	1.00
12	Beakers, 150 to 250 cc.	1.50
3	Bell jars 2 feet high and 10 inches in diameter	14.40
3	Bell jars about 8 inches high and 10 inches in diameter	5.00
1	Bell jar, open top, 8 inches high and 8 inches in diameter	2.00
1 piece	Sheet rubber 2 feet square (should be kept in lightning fruit jar when not in use)	1.50
24	Lightning fruit jars (1 quart)	3.00
6	Flasks, 250 cc.	1.00
36	Petri dishes, 4 inches in diameter	6.00
1	Cylindrical graduate, 1000 cc.	1.35
1	Cylindrical graduate, 100 cc.	.40
6	Tall glass cylinders (1000 cc.)	1.75
1	Box slide labels	.10
1	Box labels, 2 × 3 inches	.18
1	Steam sterilizer, copper bottom, 18 inches high	6.00

50	8-ounce wide-mouthed bottles	$2.20
50	4-ounce wide-mouthed bottles	1.60
24	200 cc. narrow-mouthed bottles with ground glass stoppers	2.60
100	Vials with corks, 3 inches high, 1 inch in diameter	2.75
100	Corks to fit 8-ounce wide-mouthed bottles	1.00
100	Corks to fit 4-ounce wide-mouthed bottles	.75
100	Corks to fit 6-inch test tubes	.40
10	Rubber stoppers with 2 holes to fit 250-cc. flasks	.45
10	Rubber stoppers with 1 hole to fit 6-inch test tubes	.30
2	Insect spreading boards	1.00

QUANTITY	CHARTS AND PREPARATIONS	ESTIMATED PRICE
11	Jung plant charts (pansy, horse-chestnut, tulip, linden, potato, carrot, pea, Spirogyra, mold, fern, moss)	$13.20
1	Teachers' Botanical Aid, 28 charts, containing 300 drawings (Western Publishing House, Chicago, Ill.)	12.50
11	Jung animal charts (fish (external), fish (internal), frog, Amœba, Paramecium, crayfish, bee, butterfly, cricket, finch, duck)	13.20
4	Leuckhart animal charts (grasshopper, bee, butterfly, metamorphosis of frog)	8.00
1	Model of heart and lungs (dissectible), natural size	12.75
1	Model of digestive system on panel, natural size	15.75
1	Model of circulatory system on panel, natural size	11.75
1	Articulated human skeleton, clutch standard	35.00
1	Life history of butterfly	6.00
1	Life history of honey bee	5.00
1	Life history of frog	5.00
1	Life history of fish	5.00
1	Half skeleton of fish (glass case)	3.00
1	Half skeleton of frog (glass case)	4.00

7	Microscopical slides of plant tissue (cross section and longitudinal section of young root, cross section and longitudinal section of stem one year old, cross section of hydrangea leaf, epidermis of leaf, separate wood cells, ducts, conjugating Spirogyra)	$3.50
5	Microscopical slides of animals (Amœba, Paramecium, frog's blood, human blood, mouth parts of bee)	3.00

QUANTITY	LIST OF CHEMICALS	ESTIMATED PRICE
2 lb.	Hydrochloric acid	$1.00
1 lb.	Nitric acid	.28
1 lb.	Ammonia	.26
1 oz.	Iodine	.30
5 oz.	Potassium iodide	.90
1 lb.	Ether	.40
1 lb.	Caustic soda	.30
1	Small tube red litmus paper	.08
1	Small tube blue litmus paper	.08
1 gal.	95 per cent alcohol	3.50
10 lb.	40 per cent formalin	1.70
8 oz.	Glycerin	.25
1 oz.	Pepsin	.30
1 lb.	Peptone	2.00
1 oz.	Taka diastase	1.70
1 lb.	Salt	.05
1 oz.	Phosphate of lime	.12
1 lb.	Grape sugar	.12
½ lb.	Cooking soda	.10
1 lb.	Copper sulphate	.35
1 lb.	Rochelle salt	.30
1 jar	Beef extract	.75
1 lb.	Agar	.90
½ lb.	Powdered sulphur	.07
1 lb.	Potassium chlorate	.20

½ lb.	Manganese dioxid	$.35
1 lb.	Granulated zinc	.25
1 lb.	Absorbent cotton	.35
6	Small candles	.10
1 lb.	Marble pieces	.10
5 lb.	Plaster of Paris	.10
5 oz.	Potassium cyanide	.10
1 oz.	Ferric chloride	.05
1 lb.	Corn starch	.10
½ lb.	Arrow root starch	.15
1 oz.	White egg albumen	.12
1 oz.	Powdered carmine	.40
1 oz.	Gluten	.15

APPENDIX II

ORDER OF TOPICS

The following order of topics, with time assignment for each, has been found by the authors to be satisfactory:

I. Course begun in September and completed in June.	
1. The general structure of plants (organs of a plant)	2 lessons
2. Reproduction in plants.	
a. Structure and adaptations of flowers	15 lessons
b. Structure and adaptations of fruits, including fruit and seed dispersal	5 lessons
3. Plant propagation.	
a. Seeds and their development into plants	6 lessons
b. Conditions essential for the growth of plants	2 lessons
4. Cellular structure of plants, including fertilization of flowers	5 lessons
5. Composition of living and lifeless things.	
a. Elements, compounds, oxidation, with definitions	10 lessons
b. Composition of food substances, with tests for each	8 lessons
c. Manufacture of food substances by plants	5 lessons
6. Osmosis and digestion	5 lessons
7. Adaptations of the nutritive organs of plants.	
a. Structure and adaptations of roots	5 lessons
b. Structure and adaptations of stems	3 lessons
c. Structure and adaptations of leaves	4 lessons
8. Respiration and the production of energy in plants	4 lessons
9. Plants in their relation to human welfare.	

a. Some uses of plants to man	3 lessons
b. Forests and forest conservation	3 lessons
10. Single-celled animals	5 lessons
11. Fish (and frog, if this form is taught)	14 lessons
12. The general structure of the human body	3 lessons
13. Microörganisms and their relation to human welfare	10 lessons
14. Nutrients and their uses	7 lessons
15. Stimulants, narcotics, and poisons	10 lessons
16. Digestion of the nutrients	7 lessons
17. Circulation of the nutrients	6 lessons
18. Respiration and the production of heat and power in man	7 lessons
19. Additional topics in hygiene	9 lessons
20. Birds	5 lessons
21. Insects	15 lessons

II. Course begun in February and completed in January.

1. Composition of living and lifeless things.	
a. Elements, compounds, oxidation, with definitions	10 lessons
b. Composition of food substances, with test for each	8 lessons
c. Manufacture of food substances by plants	5 lessons
2. General structure of plants, including cellular structure	5 lessons
3. Osmosis and digestion	5 lessons
4. Adaptations of the nutritive organs of plants.	
a. Structure and adaptations of roots	5 lessons
b. Structure and adaptations of stems	3 lessons
c. Structure and adaptations of leaves	4 lessons
5. Respiration and the production of energy in plants	4 lessons
6. Reproduction in plants.	
a. Structure and adaptations of flowers	15 lessons
b. Structure and adaptations of fruits, including fruit and seed dispersal	5 lessons

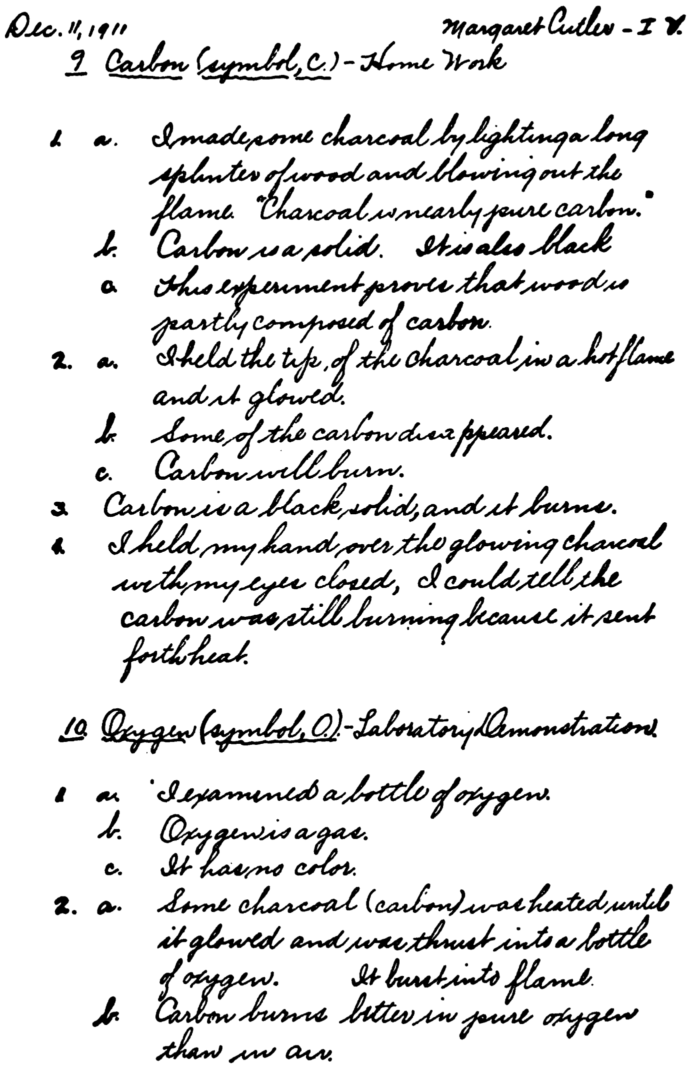
7. Plant propagation.	
a. Seeds and their development into plants	6 lessons
b. Conditions essential for the growth of plants	2 lessons
8. Plants in their relation to human welfare.	
a. Some uses of plants to man	3 lessons
b. Forests and forest conservation	3 lessons
9. Insects	15 lessons
10. Birds	5 lessons
11. Fish (and frog, if this form is taught)	14 lessons
12. Single-celled animals	5 lessons
13. The general structure of the human body	3 lessons
14. Microörganisms and their relation to human welfare	10 lessons
15. Nutrients and their uses	7 lessons
16. Stimulants, narcotics, and poisons	10 lessons
17. Digestion of the nutrients	7 lessons
18. Circulation of the nutrients	6 lessons
19. Respiration and the production of heat and power in man	7 lessons
20. Additional topics in hygiene	9 lessons

APPENDIX III

BIOLOGY NOTE-BOOKS

Method of Recording Laboratory Observations. — In preparing note-book records of laboratory observations or experiments, home work, or field trips, the teacher should insist, so far as possible, that pupils give in clear, concise English a complete account of the work that has been done. Students should be careful to state the purpose of the experiment, and describe the preparation of the experiment. He should indicate whether the work was done by himself or by some one else. The results observed should be sharply distinguished from the conclusions derived from observation. Pupils might well use as paragraph titles the section titles printed in heavy face type (*e.g. Carbon, Oxygen*, etc.). On pp. 182–183 are two accounts of the same experiments that were photographed from the note-books of two different pupils. The method of writing up an experiment shown in Fig. 88 is suggested for accounts that are written in the laboratory; that in Fig. 89, for accounts written at home.

Drawings. — In making drawings pupils should be supplied with sharp-pointed pencils that are relatively hard. Clear outline drawings should be insisted upon, and shading should as a rule not be encouraged (Figs. 90, 91). The general title of the sheet of drawings should be placed at the top of the sheet. When there are several drawings on the same sheet, the general title should be placed at the top, and the special title of each should be written just below the individual drawing. In labeling, the dotted leaders may run in any direction (see pp. 184–187), but they should not cross each other. The labels, however, should all be written parallel to the top margin



Dec. 11, 1911 Margaret Cutler - I V.

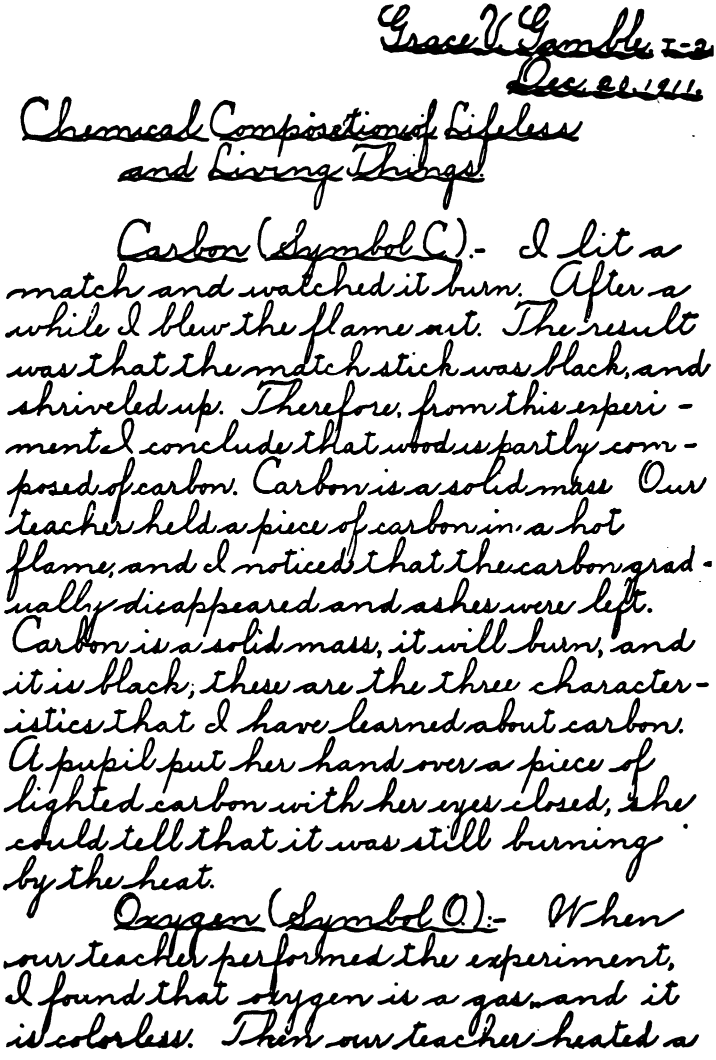
9 Carbon (symbol, C.) - Home Work

1. a. I made some charcoal by lighting a long splinter of wood and blowing out the flame. "Charcoal is nearly pure carbon."
   b. Carbon is a solid. It is also black
   c. This experiment proves that wood is partly composed of carbon.
2. a. I held the tip of the charcoal in a hot flame and it glowed.
   b. Some of the carbon disappeared.
   c. Carbon will burn.
3. Carbon is a black, solid, and it burns.
4. I held my hand over the glowing charcoal with my eyes closed, I could tell the carbon was still burning because it sent forth heat.

10 Oxygen (symbol, O) - Laboratory Demonstrations.

1. a. I examined a bottle of oxygen.
   b. Oxygen is a gas.
   c. It has no color.
2. a. Some charcoal (carbon) was heated until it glowed and was thrust into a bottle of oxygen. It burst into flame.
   b. Carbon burns better in pure oxygen than in air.

FIG. 88. — Specimen page from a note-book.



Grace V. Gamble. I-2
Dec. 22. 1911.

Chemical Composition of Lifeless and Living Things.

Carbon (Symbol C.).- I lit a match and watched it burn. After a while I blew the flame out. The result was that the match stick was black, and shriveled up. Therefore, from this experiment I conclude that wood is partly composed of carbon. Carbon is a solid mass. Our teacher held a piece of carbon in a hot flame, and I noticed that the carbon gradually disappeared and ashes were left. Carbon is a solid mass, it will burn, and it is black; these are the three characteristics that I have learned about carbon. A pupil put her hand over a piece of lighted carbon with her eyes closed, she could tell that it was still burning by the heat.

Oxygen (Symbol O.):- When our teacher performed the experiment, I found that oxygen is a gas, and it is colorless. Then our teacher heated a

FIG. 89. — Specimen page from a note-book.

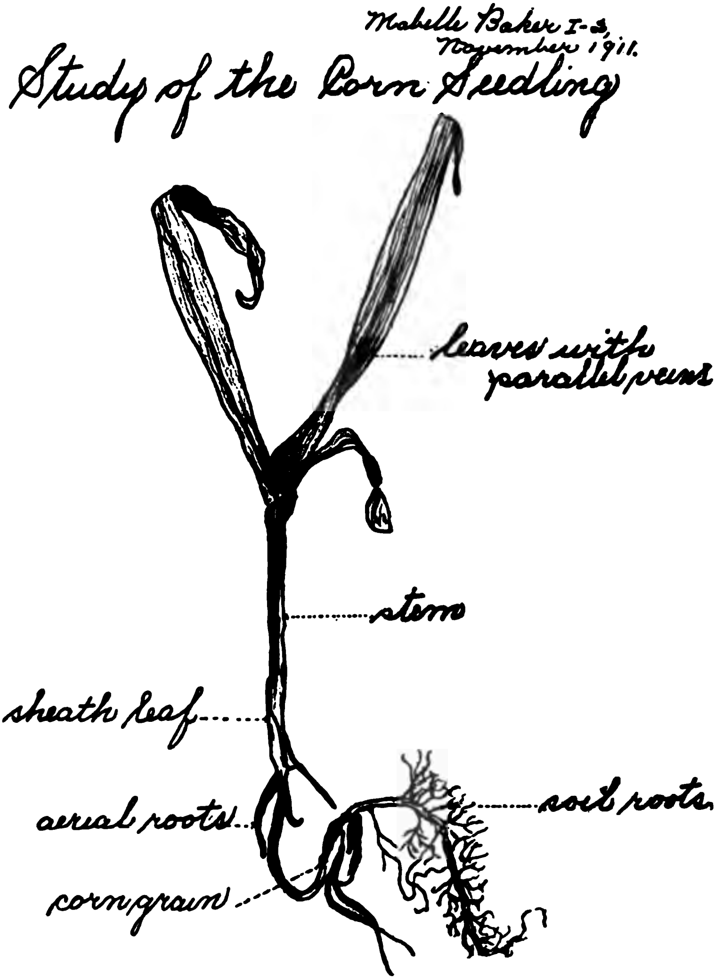


Fig. 90. — Drawing of an advanced stage of the corn seedling.

of the sheet. If the drawings are made on separate sheets of paper about the size of a page in the note-book, the sheets may be collected, criticized, and rated, and then, if the left-hand margin of about an inch is folded, the drawings can be fastened in the note-book by pasting this narrow flap.

The following directions for guiding pupils in the preparation of their note-books have been found by the authors to be of great assistance.

1. In the upper right-hand corner of the outside front cover of your note-book write your name, division (*i.e.* grade and section), and the classroom in which you meet at 9 A.M. thus:

   JOHN S. JONES, I–8 (or IA)
   Room 416

   Across the middle of the front cover write BIOLOGY NOTE-BOOK.
2. Cover your note-book with manila paper, and on the front cover put the information called for in 1 above. Be sure to keep your note-book covered.
3. Write your name, division, and classroom in the upper right-hand corner of the first page of your note-book. Leave the rest of this page blank for the teacher's ratings and comments.
4. Number each page of your note-book.
5. On each of the pages draw a vertical line about an inch from the left margin. Always leave this marginal space for the teacher's comments.
6. Begin each new subject on a new page, writing its title on the first line. The first composition or notes should commence on page 5, the preceding pages being reserved for index.
7. Write your compositions or notes in ink on both sides of the page.
8. Indent about an inch the first word of each paragraph. All other lines should begin at the left margin line. It is

suggested that the paragraph titles used in the laboratory studies be employed and that they be underlined (*e.g.* Parts of a Leaf).

9. Make sure that your statements in each paragraph or in your notes are sufficiently full and clear to be readily intelligible to one who knows nothing of the subject.
10. In your compositions or notes be careful to make clear what you yourself *did*, what you *saw*, what you *heard*, and what you *read*. Accounts of experiments may often be written in four paragraphs as follows: object of experiment; preparation of experiment; result of experiment; conclusion from experiment.
11. If, on account of absence, it is necessary that work be copied, inclose such account in quotation marks, and write at the end of such quotation the name of the pupil from whom the account was copied.
12. Every correction indicated by the teacher should be made by the student as soon as the note-book is returned.
13. Every student who wishes to do so can produce a first class note-book, neat in appearance, and at least relatively free from mistakes in spelling, punctuation, and grammar.

MARKS USED IN THE CORRECTION OF BIOLOGY PAPERS

cp = mistake in use or in omission of capital letter.
cl = meaning not clear.
gr = mistake in grammar.
I = statement incomplete or wanting.
n = composition is lacking in neatness.
¶ = error in paragraphing.
p = mistake in punctuation.
r = repetition of word or idea.
sp = error in spelling.
w = word improperly used.
? = doubt as to the truth of the statement.
( ) = words in parenthesis are to be crossed out.

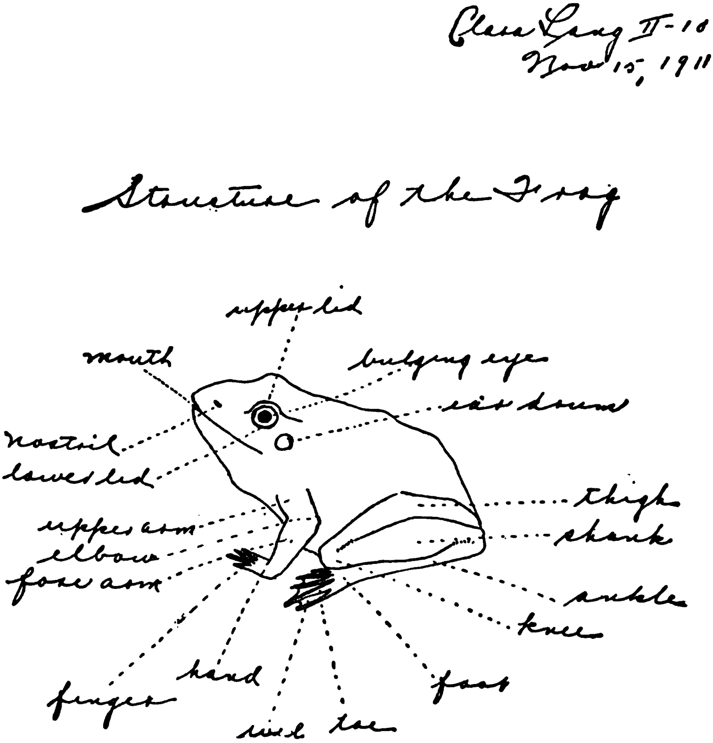


FIG. 91. — Drawing of side view of frog.

APPENDIX IV

REVIEW TOPICS IN PLANT BIOLOGY

You should be prepared to give a good oral recitation on each of the following topics. If you are not sure of any of the facts called for, write down the topic or topics, and ask your teacher at the beginning of the next recitation how to obtain the information.

A. COMPOSITION OF LIFELESS AND LIVING THINGS.

1. *Chemical element:* definition; examples with symbols of each; characteristics of each (*i.e.* whether it is solid, liquid, or gas; color, odor, and taste; ability of each to burn or to cause burning).
2. *Oxidation:* definition; chemical element necessary; compound formed by the oxidation of elements; evidences of oxidation.
3. *Chemical compound:* definition; examples; test for two of them, with characteristics of each (as in 1 above).
4. *Food substances:* kinds; chemical composition of each; test for each; examples of foods containing each in abundance.
5. *Manufacture of food substances by plants:* proofs of the necessity of sunlight, chlorophyll, and carbon dioxide for carbohydrate manufacture; proofs of the excretion of oxygen in carbohydrate manufacture; manufacture of proteins.

B. GENERAL STRUCTURE OF PLANTS.

1. Parts of a plant; organs and functions.
2. Structure of plant cells; protoplasm; assimilation, growth, and cell division.

C. OSMOSIS AND DIGESTION.

1. Proofs that water and grape sugar will pass through a membrane; definition and law of osmosis.
2. Proofs that starch and protein will not pass through a membrane; digestion of starch; definition of digestion; digestive ferments.

D. ADAPTATIONS OF THE NUTRITIVE ORGANS OF PLANTS.

1. *Roots:* gross structure; structure of a root-hair; functions of roots; adaptations of roots.
2. *Stems:* gross structure of a woody stem; functions of stems; adaptations of stems; changes in stems during growth.
3. *Leaves:* gross and microscopical structure; functions of leaves; adaptations of leaves.

E. RESPIRATION AND THE PRODUCTION OF ENERGY IN PLANTS.

1. *Energy:* examples in plants; proof that heat energy is developed in growing seedlings; transformations of energy; source of energy; oxidation as a means of liberating energy.
2. *Respiration:* definition; proof of the necessity of air for plants and of the production of carbon dioxide by plants.

F. REPRODUCTION IN SEED-PRODUCING PLANTS.

1. *Floral envelopes:* names of the parts of each floral envelope; position and general description of the floral envelopes in the flowers studied; functions of each of the floral envelopes.
2. *Essential organs:* name, number, position, and parts of each of the essential organs; general description and functions of the parts of each of the essential organs.
3. *Pollination.*
   - *a.* Self-pollination: definition; devices to prevent it in flowers studied.
   - *b.* Cross-pollination: definition; devices to make it possible in flowers studied; agencies which secure cross-pollina-

tion; comparative vigor of plants from seeds resulting from cross-pollinated and from self-pollinated flowers.

4. *Fertilization.*
   - *a.* Cellular nature of pollen and ovules; germination of pollen grains.
   - *b.* Structure of ovule.
   - *c.* Process of fertilization; production of the embryo.
5. *Fruits.*
   - *a.* Structure of each of fruits studied; definition of a fruit; classification of fruits.
   - *b.* Necessity for seed-dispersal; agencies by which seed-dispersal is brought about; adaptations of fruits and seeds to secure dispersal by each of these agencies.
   - *c.* Adaptations for protecting seeds of unripe edible fruits; adaptations for protecting seeds of ripe edible fruits.

G. PLANT PROPAGATION.

1. *Bean seed and its development into a seedling:* markings on seed; their cause or function; seed covering; position and kinds of stored food; description of parts of embryo; parts of the plant which develop from the parts of the embryo; breaking of seedling through the soil.
2. (Optional.) *Corn grain and its development into a seedling:* description of the parts of the embryo; position and kinds of stored food; breaking of seedling through the soil; various parts of the plant which develop from each of the parts of the embryo.
3. *Definitions:* seed, seedling, germination, seed coats, micropyle, hilum, embryo, cotyledon, plumule, hypocotyl, endosperm, primary and secondary roots.
4. *Experiments* to show —
   - *a.* Function of endosperm of corn grain.
   - *b.* (Optional.) Relation of water and temperature to germination.
5. (Optional.) *Other methods of plant propagation:* grafting; slips, runners, and layers; tubers; bulbs.

6. *Conditions essential for the growth of plants:* five essential conditions; conditions of soil favorable for growth; methods of soil improvement.
7. (Optional.) *Struggle for existence and its effects:* Variation among plants; numbers of seeds produced by plants; struggle for existence among plants; survival of the fittest.
8. (Optional.) *Improvement of plants by man:* artificial selection of favorable variations; artificial crossing of related species; some of the valuable crops of New York State; some of the methods of increasing crop production.

H. PLANTS IN THEIR RELATION TO HUMAN WELFARE.

1. *Some uses of plants to man.*
   - *a.* Uses of plants for food.
   - *b.* Uses of plants for flavoring extracts, beverages, and medicines.
   - *c.* Uses of plants for clothing.
2. *Forests and forest conservation.*[1]
   - *a.* Definitions.
     - (1) A forest means a growth of trees sufficiently dense to form a fairly unbroken canopy of trees. A forest has a population of animals and plants peculiar to itself, a soil of its own making, and a climate different from that of the open country.
     - (2) "Forestry is the preservation of forests by wise use." — ROOSEVELT.
   - *b.* Value of forests.
     - (1) Æsthetic value — beauty of form and color of forest trees.
     - (2) Value in affecting drainage.
       - (*a*) By retaining water in the soil through the agency of the roots.

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[1] The authors are indebted to Miss Kate B. Hixon, of the Morris High School, New York, N.Y., for the review topics on Forests and Forest Conservation.

- (b) By preventing too rapid evaporation from the soil, through the help of the foliage.
- (c) By retarding the melting of snow, thus preventing freshets.

(3) Value in affecting climate.
- (a) By bringing moisture into the air, which falls as rain.
- (b) By setting oxygen free into the air in the process of starch making.
- (c) By acting as a windbreak.

(4) Economic value.
- (a) As a source of lumber and fuel.
- (b) As a source of food (nuts, maple sugar, etc.).
- (c) As a source of industrial raw materials (paper, tanning materials, wood alcohol, tar, pitch, turpentine, rosin, fibers).

c. Dangers to forests.
- (1) Fires.
- (2) Insects.
- (3) Grazing of cattle.
- (4) Careless lumbering.
- (5) Fungi that cause disease.

d. Results of deforestation.
- (1) Main cause of freshets, which cause destruction of property and loss of life; they also fill up navigable streams with soil and débris.
- (2) Drouth, with the consequent lessening of water power.
- (3) Timber famine, especially in hard woods.

e. Methods used by the Government Bureau of Forestry to preserve forests.
- (1) Allow only the cutting of dead or mature trees.
- (2) Insist that each tree cut be replaced by another of the same kind.
- (3) Prevent the spread of fires.
- (4) Destroy insects that are injurious to trees.
- (5) Restrict cattle grazing to certain seasons.

3. *Fungi and their relation to human welfare.*

a. Bacteria; microscopical appearance and size; reproduction; necessary conditions for growth; relation (1) to soil fertility, (2) to flavors of food, (3) to the industries, (4) to diseases.

b. (Optional.) Yeast: microscopical appearance and size; reproduction; changes caused by yeast; uses of yeast.

c. (Optional.) Bread mold; structure; reproduction and life history; nutrition in the fungi.

d. (Optional.) Other fungi: mushrooms, rusts, and smuts; economic importance.

I. PLANT CLASSIFICATION.

1. *Common methods of classification.*
   - *a.* Herbs, shrubs, and trees: define each; give examples.
   - *b.* Annuals, biennials, and perennials; define each; give examples.
   - *c.* Deciduous and evergreen trees and shrubs: define each; give examples.
2. (Optional.) *Scientific method of classification.*
   - *a.* Seed-producing plants.
     - (1) Gymnosperms and angiosperms.
     - (2) Monocotyledons and dicotyledons.
     - (3) Plant family, genus, species, variety.
   - *b.* Spore-producing plants.
     - (1) Ferns: fern plant; spores; prothallus; fertilization of the egg-cells; alternation of generations.
     - (2) Mosses: moss plant; protonema; sexual generation; alternation of generations.
     - (3) Algæ: Spirogyra, its structure, methods of reproduction and functions; Pleurococcus and other algæ.
     - (4) Fungi (see H, 3, above).

Note. The following outlines were prepared by Miss Martha F. Goddard, late of the Morris High School, New York, N.Y. They furnish an admirable review of the most important nutritive and reproductive functions of plants. Pupils might either copy the whole outline into their note-books, supplying the words represented by the figures, or make a list of the words, numbering them to correspond to the figures below.

NUTRITION IN GREEN PLANTS THAT PRODUCE SEEDS

Soil-water, in which are dissolved compounds that contain nitrogen and other mineral matters needed by the plant, is absorbed by (1) which are (2) found (3) of roots. The process by which this soil-water enters is called (4). In the root-hair the membrane is the (5). More liquid enters the root-hair than passes out, because (6). The substances admitted in the soil-water are regulated by the action of the (7) in the cell, through which the liquid must pass. The cell-sap passes from one cell of the root to the next, until it reaches thick-walled tubular cells called (8), which form part of the (9) of the root, stem, and leaf. The liquid passes up through these until it reaches spaces between the thin-walled leaf-cells, and finally the sap gets into these cells.

A gas called (10) is taken in through epidermis cells of the leaf, and through openings called (11) between certain cells of the epidermis that are known as (12). In the soft cells of the inside of the leaf are tiny masses of protoplasm which contain a green coloring matter called (13). These green masses of protoplasm are called (14). They can manufacture starch out of the (15) and the (16) in the presence of (17). The elements in CO_2 and H_2O, however, are not in quite the right proportions, so (18) is given off as a waste product. The soil-water is such a weak solution of mineral matter that not all the water can be used by the plant, so this water that is not needed is given off by a process called (19). The amount of water thus given off is regulated by the action of the (20) that surround each (21).

During the night the starch is changed to (22) by a process known as (23). This liquid food then passes down through the (24) of the veins and bast or fibrous bark to places that serve for storage or to growing regions where it is used to make a substance for cell-wall building known as (25). Some of the sugar is made by the protoplasm of the plant to unite with the nitrogen of the nitrates and with the sulphur and phosphorus of other mineral matters derived from the soil, and a compound is formed called (26) which the growing regions use to make into more (27). This last change is called *assimilation.*

Some of the proteins may also be stored for future use. Food may be stored in the (28), the (29), the (30), the (31), or in any thin-walled cells.

OPTIONAL. THE LIFE-HISTORY OF A SEED-PLANT

See note, p. 193.

The mother-plant produces flowers which attract insects by their (1) or by their (2). These animals carry (3) on their hairy bodies from the (4) of one flower to the (5) of another. Here nourished by a (6) it sends out a tube which grows down through (*a*) the (7), (*b*) the (8), and (*c*) the (9), and here enters a tiny opening called the (10) in the (11). There a nucleus of the pollen grain (called a sperm nucleus) unites with a nucleus of the egg-cell in the ovule during the process of (12) to form one cell (called a fertilized egg-cell) which now develops into a tiny plant known as the (13) of the seed. This little plant has (*a*) a minute stem called the (14), (*b*) one, two, or more seed-leaves known as (15), and (*c*) usually a tiny bud called the (16).

The mother-plant feeds this embryo until it has grown thus far, and also stores up food for further growth. This may be put in the cotyledons as in the (17) seed, or it may be packed around the embryo, when it is called (18), as in the (19). To protect the embryo until time for germination, the seed has one or more outer coverings known as (20). That the seed may be carried away from the mother-plant, and so have better opportunities for development, the mother-plant provides the fruit or the seeds (*a*) with (21) or (22) so they may be carried by the wind, or (*b*) with (23) so they may cling to the wool of animals, or (*c*) with (24) so they may tempt animals to eat them; in the last case (as in the peach or cherry) the contents of the seed are protected by (25).

When the seed has favorable surroundings, namely (26), (27), and (28), it germinates. If it has one cotyledon, the plant is called (29), the woody bundles in its stem will be (30), and the veining of the leaves will probably be (31). If two cotyledons are present in the seed, the plant is called (32), the woody bundles in its stem will be arranged (33), and the veining of the leaves will be (34).

The principal food materials stored in seeds are three in number, namely, (*a*) (35), which is tested by (36); (*b*) (37), tested by (38); and (*c*) (39), tested by (40). Sometimes a fourth nutrient (41) is stored in other parts of the plant; its presence may be detected by (42).

APPENDIX V

REVIEW TOPICS IN ANIMAL BIOLOGY

The student should be prepared to give a good oral recitation on each of the following topics. If he is not sure of any of the facts called for, he should write down the topic or topics, and ask the teacher at the beginning of the next recitation how to obtain the information.

A. INSECTS.
  1. *Butterflies and moths.*
    a. Characteristics of structure: regions; organs of the head (eyes, antennæ, proboscis); wings and their scales; legs; abdomen.
    b. (Optional.) Experiments to show methods of feeding and flying.
    c. Reproduction and life history.
    d. Economic importance: cabbage butterfly; tussock moth; gypsy moth; brown-tail moth; codling moth; clothes moth; silkworm.
  2. *Grasshoppers and their relatives.*
    a. Characteristics of structure: regions; organs of the head (eyes, antennæ, mouth parts); legs and their parts; wings; abdomen.
    b. Experiments to show methods of feeding, locomotion, and breathing.
    c. Reproduction and life history; direct and indirect metamorphosis.
    d. Economic importance; relatives of the grasshopper.
  3. *Bees and their relatives.*
    a. Characteristics of structure; regions; organs of head

(eyes, antennæ, mouth parts); adaptations of mouth parts and legs for collecting nectar and pollen.

- b. Queen and drones: reproductive functions of each.
- c. Work of the hive: comb building; pollen gathering; honey making; care of young; protection and ventilation of the hive.
- d. History of beekeeping; life history of honeybee; swarming.
- e. Economic importance of bees.
- f. Relatives of bees.

4. *Mosquitoes and flies.*
   - a. Life history of house mosquito (Culex).
   - b. Life history of malaria-transmitting mosquito (Anopheles).
   - c. Proofs that malaria is transmitted by Anopheles mosquito; life history of malaria parasite.
   - d. Proofs that yellow fever is transmitted by Stegomyia mosquito.
   - e. Methods of exterminating mosquitoes.
   - f. House flies: feeding habits; relation to disease; life history; methods of extermination.
5. (Optional.) *Other topics on insects.*
   - a. Losses due to insect pests.
   - b. Insecticides.

B. BIRDS.

1. *Characteristics of structure:* regions; organs of head; wings and their adaptations for flight; (optional) legs.
2. *Reproduction and life history:* structure and formation of egg; fertilization and development of embryo; nests and care of young.
3. (Optional.) *Classification of birds:* common methods of classification; scientific classification with characteristics of each group (*e.g.* swimming, wading, and scratching birds; birds of prey; woodpeckers; perching birds).
4. (Optional.) *Migration of birds:* identification of birds.
5. *Importance of birds to man:* as destroyers of harmful insects; as destroyers of weed seeds; as destroyers of rats and mice; as scavengers.

6. *Birds injurious to man.*
7. *Decrease in bird life:* by cats; by boys; for food; for millinery purposes; effects of bird destruction.
8. *Conservation of birds:* legislation; creation of public sentiment; how girls and boys can help; feeding of birds and building of bird houses.

C. FROGS AND THEIR RELATIVES.

1. *Characteristics of structure:* regions; organs of head with position of each; arms and legs, position and parts of each.
2. *Locomotion:* adaptation for swimming and jumping.
3. *Food getting and digestion:* kinds of food eaten; adaptations for securing and swallowing food; digestive organs and digestion.
4. *Circulation:* parts of circulatory system with adaptations of each.
5. *Breathing and respiration:* definitions; location of air passages and lungs; inspiration and expiration; adaptations of lungs, blood vessels, and skin; oxidation and the release of energy.
6. *Habits of frogs:* enemies; adaptations for protection.
7. *Reproduction:* formation of eggs; development of embryo; changes in organs of locomotion, digestion, circulation, and respiration during life history.
8. *Relatives of frogs.*
9. *Economic importance of Amphibia.*

D. FISHES.

1. *Characteristics of structure:* regions; organs of head with position of each; structure of fins; differences in form of body and position of fins in various kinds of fishes.
2. *Locomotion:* adaptations of body regions and fins.
3. *Food getting and digestion:* kinds of food eaten; adaptation for securing and swallowing food; digestive organs and digestion.
4. *Circulation:* parts of circulatory system with adaptations of each.

5. *Breathing and respiration:* definitions; breathing movements, cause and effect of each; adaptations of gills (including blood vessels); oxidation and the release of energy.
6. *Reproduction:* formation of eggs and sperm-cells; fertilization; development of embryo; food supply for embryo; artificial propagation.
7. *Economic importance:* (*a*) for food, (*b*) for other purposes; methods of preparing fish.
8. *Salmon and codfish:* geographical distribution; food and feeding habits; breeding habits; methods of catching.
9. *Conservation of fish:* disappearance of Atlantic salmon; decrease of Pacific salmon; work of National and State Governments; laws for the protection of fishes.

E. CRAYFISHES AND THEIR RELATIVES.

1. *Regions and appendages.*
2. *Adaptations* for walking and swimming.
3. *Food, food getting, and digestion.*
4. *Adaptations* for breathing; respiration and the production of energy.
5. *Habits:* enemies; adaptations for protection.
6. *Reproduction and life history.*
7. *Relatives of crayfish.*
8. *Economic importance of Crustacea.*

F. PROTOZOA.

1. *Paramecium:* structure; locomotion; food, food getting and digestion; respiration and liberation of energy; excretion; reproduction.
2. (Optional.) *Amœba:* (use same topics as in 1 above).
3. *Comparison of Protozoa with higher animals.*
4. *Economic importance of Protozoa.*

G. (Optional.) ADDITIONAL ANIMAL STUDIES.

1. *Sponges:* structure; functions; economic importance.
2. *Hydra:* structure; adaptations for locomotion, food getting, digestion, and respiration; reproduction; relatives.
3. *Earthworm:* structure; adaptations for locomotion; food getting and digestion; economic importance; relatives.

4. *Fresh-water mussel:* structure; adaptations for protection, locomotion, eating, and breathing; relatives.
5. *Turtle:* structure; adaptations for protection, locomotion, and eating; relatives.
6. *Mammals:* distinguishing characteristics of structure; sense organs; teeth; appendages; economic importance; reproduction.

APPENDIX VI

REVIEW TOPICS IN HUMAN BIOLOGY

The student should be prepared to give a good oral recitation on each of the following topics. If he is not sure of any of the facts called for, he should write down the topic or topics and ask the teacher at the beginning of the next recitation how to obtain the information.

A. THE GENERAL STRUCTURE OF THE HUMAN BODY.

1. *Regions of the human body:* external regions; general plan of internal structure.
2. *Organs of the body:* definition; examples, with functions of each.
3. *Tissues of the body:* examples, with characteristics of each.
4. *Cells of the body:* protoplasm; assimilation, growth, and cell division; cells of mouth; cells of the blood, and of other tissues.

B. MICROÖRGANISMS AND THEIR RELATION TO HUMAN WELFARE.

1. *Bacteria:* microscopical appearance and size; reproduction; spore formation.
2. *Occurrence of bacteria:* proofs of their presence, (*a*) in air, (*b*) in water, milk, and other foods, (*c*) on various parts of the human body; effects of (*a*) different degrees of temperature (including Pasteurization of milk), (*b*) lack of moisture, (*c*) antiseptics.
3. *Bacteria as the friends of man:* relation, (*a*) to soil fertility, (*b*) to flavors of food, (*c*) to linen and other industries.
4. *Bacteria as the foes of man:* injurious effects of bacteria; methods of food preservation; proper methods of sweeping and dusting, with experiments; treatment of cuts; tuber-

culosis, its cause, prevention, and cure; pneumonia, its cause and prevention; diphtheria, its cause, treatment, and prevention; typhoid fever, its cause and prevention; water and milk supplies; (optional) smallpox and vaccination; (optional) hydrophobia and the Pasteur treatment; cause and prevention of other diseases; safeguards of the body against disease.

C. FOODS AND THEIR USES.

1. *Food substances found in the human body:* presence of proteins, fats, carbohydrates, mineral matters, and water in various parts of the human body.
2. *Necessity of foods:* (*a*) for growth, (*b*) for repair, (*c*) for the production of energy.
3. *Definition of a food.*
4. *Composition of foods:* food substances in milk; difference in the composition of animal and vegetable foods.
5. *Uses of each of the food substances:* comparison of the uses of the nutrients.
6. *Cooking of foods:* importance of proper cooking; reasons for cooking animal foods; principles involved in, (*a*) frying, (*b*) making soups, (*c*) stewing, (*d*) boiling meats, (*e*) roasting and broiling; reasons for cooking vegetables; boiling vegetables; bread making.
7. *Food economy:* importance of food economy; comparative cost of foods; economy in the purchase of foods; economy in the use of foods.
8. *Daily diet:* amount of each nutrient required; necessity for a mixed diet; avoidance of indigestible foods; sugar as a part of the diet.

D. STIMULANTS AND NARCOTICS.

1. *Definition* and examples of each.
2. *Tea and coffee:* preparation of each; effect of each on body; use and abuse of each.
3. *Chocolate, cocoa, and other beverages:* composition; effects on body.
4. *Alcoholic beverages:* composition; alcohol as a stimulant and

narcotic; effects of small and large quantities of alcohol; Professor Hodge's experiment on dogs, as to the effects of moderate amount of alcohol in relation to, (*a*) activity, (*b*) skill and endurance, (*c*) nervousness, (*d*) offspring of the dogs, (*e*) resistance to disease; effect of alcohol on human beings in relation to, (*a*) mental activity, (*b*) muscular activity, (*c*) manual dexterity, (*d*) resistance to disease; alcohol and life insurance; business arguments for total abstinence; cost of intemperance.

5. *Tobacco:* effects, (*a*) on growth, (*b*) on mental development; tobacco and athletics.
6. *Drugs and patent medicines:* opium (morphine, laudanum, paregoric); acetanilid; dangers in the use of patent medicines; pure food and drug law.

E. DIGESTION AND ABSORPTION.

1. *General survey of the digestive system:* necessity for digestion; parts of the alimentary canal; digestive glands.
2. *Mouth cavity:* walls of the mouth cavity; structure and functions of the tongue.
3. *Teeth:* arrangement, kinds, number of each kind, functions; milk teeth; structure and care of teeth.
4. *Saliva and its functions:* experimental proof of the digestion of starch by saliva; position and action of salivary glands; uses of saliva.
5. (Optional.) *Throat cavity and gullet:* structure; functions.
6. *Stomach:* position, size, shape; lining of stomach and gastric glands; muscles of stomach; digestion in the stomach.
7. *Small intestine:* position, form, size; (optional) peritoneum; digestion in the small intestine.
8. (Optional.) *Large intestine:* position, form, size; vermiform appendix.
9. *Absorption from the alimentary canal:* necessity for absorption; absorption in mouth, throat, gullet, and stomach; absorption in the small and large intestine.
10. (Optional.) *Liver:* position, form, size; functions of the liver; functions of the bile.

11. *Hygiene of digestion:* hygienic habits of eating; prevention of disease; the use of water as a drink; effect of alcoholic drinks on the organs of digestion.

F. CIRCULATION OF THE NUTRIENTS.
  1. *Blood:* structure of corpuscles; composition of plasma; hygiene of plasma.
  2. *Circulation:* definition; necessity for; organs of circulation, definition of each.
  3. *Heart:* position, size, shape; chambers, position and structure of each; valves; action of heart.
  4. *Blood vessels:* position and structure of arteries; variations in pulse rate; valves in arteries; position, importance, and structure of capillaries: position and structure of veins.
  5. *Course of the blood through the body:* changes in the composition of the blood.
  6. *Hygiene of the circulation:* effect of exercise on the heart and blood vessels; stopping of blood flow in wounds.

G. RESPIRATION AND THE PRODUCTION OF ENERGY IN MAN.
  1. *Necessity for respiration:* proofs of oxidation in the human body; examples of energy in the human body; transformations of energy; respiration in plants, in animals, and in man.
  2. *Adaptations for securing oxygen and for excreting carbon dioxid:* course taken by the air; nose cavity; throat and larynx; lining of the air passages; the lungs, their structure and blood supply; function of red corpuscles; change in color of blood after mixing with oxygen; hygiene of red corpuscles.
  3. *The process of breathing:* structure of the chest cavity; (optional) pleura; enlargement of chest cavity; how air is taken into the lungs; breathing capacity of lungs; expiration.
  4. *Hygiene of respiratory organs:* hygienic habits of breathing; effect of exercise on respiration; effect of tight clothing upon respiration; diseases of respiratory organs; suffocation; necessity of ventilation; methods of ventilation.

H. (Optional.) ADDITIONAL TOPICS IN HUMAN BIOLOGY.

1. *The skin:* characteristics; uses; layers; glands; importance of bathing; kinds of baths; care of the hair; care of the nails; treatment of burns; clothing; effect of alcohol on body temperature.
2. *The skeleton:* necessity for the skeleton; skeleton of the neck and trunk; skeleton of the arms and legs; skeleton of the head; joints; food and the skeleton; effect of pressure on the bones; fractures; dislocations; sprains.
3. *The muscles:* importance of muscle tissue; kinds of muscle; conditions necessary for healthy muscles (food, fresh air, exercise, rest); relation of muscles to posture.
4. *The nervous system:* the body as a collection of organs; coöperation of the organs; functions of the nervous system; parts of the nervous system; cellular structure of the nervous system; nerve impulses; reflex, conscious, and habitual activities; importance of habit; conditions necessary for a healthy nervous system (food, fresh air, varied activity, rest); effect of alcohol on the nervous system.
5. *The eyes:* protection for the eyes; structure of the eye; the eye as a camera; sensations of sight; defective eyes; hygiene of the eyes.
6. *The ears:* the external ear; the middle ear; sensations of sound.

I. (Optional.) THE LIVES AND WORKS OF GREAT BIOLOGISTS.

APPENDIX VII

LIST OF SUGGESTED BOOKS OF REFERENCE IN BIOLOGY

GENERAL BIOLOGY

1. Cyclopedia of American Agriculture. Edited by L. H. Bailey. 4 vols.—The Macmillan Co., N. Y. City. $20 net. Vol. I, Farms; Vol. II, Crops; Vol. III, Animals; Vol. IV, The Farm and the Community. We do not hesitate to say that Vols. II and III of this series are the most valuable books of reference known to us for teachers or students in plant and animal biology. Experts on the many subjects treated have epitomized in a readable form a vast amount of information which could only be found by patient search through many volumes. If schools cannot purchase these books, teachers might well urge that they be put on the shelves of the public library, for all four volumes will be found of great value as books of general reference, especially in rural communities.
2. Nature Study and Life, by Dr. C. F. Hodge.—Ginn and Co. $1.20. Contains many suggestions for the teaching of both plant and animal biology.
3. General Biology, by Sedgwick and Wilson.—Henry Holt and Co. $1.75. While mainly devoted to a consideration of the earthworm and the fern (both optional topics), this book will give teachers a clear idea of the biology of a plant and of an animal, and of the composition and characteristics of protoplasm. It also contains an admirable account of yeast, bacteria, Amœba, and Paramecium.
4. Teaching of Biology, by Lloyd and Bigelow.—Longmans, Green and Co. $1.50. Deals largely with methods of teaching nature study, botany, zoölogy, and human physiology.

PLANT BIOLOGY

5. Practical Botany, by Bergen and Caldwell.—Ginn and Co. $1.30.
6. College Botany, by G. F. Atkinson.—Henry Holt and Co. $1.50.
7. Readers in Botany, by Jane C. Newell.—Ginn and Co. 2 vols. $.60 each.
8. How to know the Wild Flowers, by Mrs. William Starr Dana. —The Macmillan Co. $1.50.
9. How to know the Fruits, by Maude G. Peterson.—The Macmillan Co. $1.50.
10. Tree Book, by Julia E. Rogers.—Doubleday, Page and Co. $4.
11. Primer of Forestry. Vols. I and II. Gifford Pinchot.—U. S. Dept. of Agriculture.
12. New Creations in Plant Life, by W. S. Harwood.—The Macmillan Co. $1.75.
13. Bacteria, Yeast, and Moulds in the Home, by H. W. Conn.—Ginn and Co. $1.
14. Farmers' Bulletins, which can be obtained free by applying to the U. S. Dept. of Agriculture, Washington, D.C. The various Bulletins contain many important facts relating to both animals and plants.

ANIMAL BIOLOGY

15. Animal Life, by Jordan and Kellogg.—Appleton. $1.20.
16. General Zoölogy, by Linville and Kelly.—Ginn and Co. $1.50.
17. American Natural History (vertebrates only), by W. T. Hornaday. $3.50.
18. Our Vanishing Wild Life, by W. T. Hornaday.—Chas. Scribner's Sons. $1.50.
19. Insect Book, by L. O. Howard.—Doubleday, Page and Co. $3.
20. Manual of Insects, by Comstock.—Comstock Publishing Co., Ithaca, N.Y. $3.75.
21. Insect Pests of Farm, Garden, and Orchard, by E. D. Sanderson.—John Wiley. $3.

22. Birds of Northeastern United States, by Frank Chapman.—Appleton. $3.
23. Bird Life (with colored plates), by Frank Chapman.—Appleton. $2.
24. Relation of Birds to Man, by Weed and Dearborn. Lippincott. $2.50.
25. Useful Birds and their Protection. Forbush. Mass. Dept. of Agriculture, Boston, Mass. $1.
26. Food and Game Fishes, by Jordan and Everman.—Doubleday, Page and Co. $4.
27. Farmers' Bulletins (see 14 above).
28. Story of the Fishes, by J. N. Baskett.—Appleton. $.65.

HUMAN BIOLOGY

29. The Human Mechanism, by Hough and Sedgwick.—Ginn and Co. $2.50.
30. General Physiology, by W. H. Howell.— W. B. Saunders. $4.
31. Studies in Physiology, by James E. Peabody.—The Macmillan Co. $1.10.
32. Laboratory Exercises in Anatomy and Physiology, by James E. Peabody.—Henry Holt and Co. $.60.
33. Infection and Immunity, by George M. Sternberg.—Putnams. $1.75.
34. Pathogenic Microörganisms, by W. H. Park.—Lea Brothers and Co. $3.75.
35. Walter Reed and Yellow Fever, by H. A. Kelly.—McClure, Phillips and Co. $1.50.
36. The Malaria Mosquito, by B. E. Dahlgren.—American Museum of Natural History. $.15.
37. Fresh Air and How to Use It. Dr. Thomas Spees Carrington. —National Association for the Study and Prevention of Tuberculosis, 103 E. 22d St., New York. $1.
38. Physiological Aspects of the Liquor Problem (2 vols.). Dr. John S. Billings *et al.* Houghton & Mifflin. $4.50.

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